CHAPTER 700 STORMWATER QUALITY

SECTION 701 INTRODUCTION

701.01 Section Description

This chapter provides design criteria and information for stormwater quality best management practices, or BMPs that are required in order for newly developed or re-developed properties to comply with the City's policies for managing the quality of stormwater runoff found in Section 104.02.

701.02 Purpose and Background

Urban stormwater runoff contains many types and forms of pollutants. When compared to stormwater runoff under pre-development conditions, higher concentrations and some contaminants that are not naturally present in surface runoff from undeveloped local lands are found. Runoff from undeveloped watersheds contains sediment particles, oxygen-demanding compounds, nutrients, metals, bacteria, and other constituents. Once developed, constituent loads increase because surface runoff volumes increase and the sources of many of these pollutants both increase and have more direct runoff routes to drainage systems. The use of some chemicals, such as fertilizers, increases the availability of potential pollutants to stormwater runoff.

Runoff water quality in urban areas can be extremely detrimental to local aquatic and riparian habitat. Paved surfaces and standing water bodies for stormwater management control elevate the temperature of water entering streams. Chemicals in standing water and ponds are oxidized, resulting in depressed levels of dissolved oxygen. Increased runoff volumes and rates create scour and deposition damage to in-stream habitat. Activities in urbanized areas, such as vehicular traffic, deposit pollutants such as heavy metals and oil & grease on paved surfaces where they easily wash off into the streams. All roadway construction and improvement projects that disturb more than ½ acre must meet the requirements of this chapter.

Best management practices (BMPs), both structural and non-structural, can reduce the amount of pollutants in stormwater. This section of the manual establishes minimum standards for the design, maintenance, application, and construction of structural water quality BMPs. The information provided in this chapter allows developers and designers to comply with the performance criteria for stormwater quality management found in Section 104.02 by providing procedures to be followed when preparing a BMP plan for compliance.

BMPs discussed in this chapter are referred to post-construction BMPs, practices intended to control the quality of stormwater runoff after construction has been completed and the site has been stabilized. Installing certain BMPs, such as bioretention areas and sand filters, prior to stabilization can cause failure of the measure due to clogging from sediment. However, with a strict construction sequence, detention ponds and other BMPs can be installed initially during construction and used as sediment control measures. In those instances, the construction sequence must require that the pond(s) or installed BMP(s) are cleaned out with pertinent elevations and storage and treatment capacities reestablished as noted in the approved stormwater management plan.

701.03 Stormwater Quality Control Requirements

The City of Indianapolis has adopted a countywide stormwater runoff quality policy (Section 104.02) based on the control of total suspended solids and floatables in stormwater runoff. In addition, designers may be required to include the control of fecal bacteria or pollutants that are associated with a specific land use, such as hydro-carbons that are associated with retail gasoline outlets, in their designs. The water quality design requirements are as follows;

1. TSS. BMPs must be capable of removing 80% of the TSS load from post-construction runoff. For the purposes of this requirement, TSS is defined as particles smaller than 125 microns in diameter. Larger material is considered to be part of the total solids load of the stormwater runoff.

2. Floatables. BMPs shall incorporate floatables control. The goal of this requirement is to capture floating debris and remove it as part of the routine maintenance of the BMPs. Standalone BMPs must include floatables control. For BMP systems, or treatment trains, at least one of the components of the BMP system, located after the last inflow point to the system, must provide control of floatables.

All new development projects requiring stormwater management plans (as noted in Section 101.03 of this manual) shall be required to address the above water quality criteria. Redevelopment projects will be required to obtain stormwater quality approval if the redevelopment activity disturbs more than ½ acre. Staff has the discretion to exempt redevelopment activities disturbing up to 5% more area.

701.04 Stormwater Quality Design Methods

Criteria have been developed that will allow designers to meet the water quality targets identified in Section 104.02. There are two categories of design methods currently in use in the City of Indianapolis: performance-based design for pre-approved BMPs, and proprietary design for innovative BMPs.

1. Performance Based Design

Performance based design of BMPs is the most prevalent design basis for stormwater quality control structures nationwide. This family of design standards is based on the common physical properties of numerous BMPs whose pollutant removal performance were measured by comparing inlet and outlet samples collected from the devices. The underlying assumption for this type of BMP design is that if a BMP is designed and constructed according to performance based design criteria, and the BMP is properly maintained, then the BMP is expected to perform at or near the efficiency reported in the design standards.

In order to meet the TSS removal goals, performance based BMPs must be designed to treat the first flush runoff. The first flush runoff volume is estimated by computation of the water quality volume (WQv), which represents the runoff volume from a storm of one inch depth over the drainage area. Based on estimates in relevant literature, including Watershed Protection Techniques[2] and the final report of the Nationwide Urban Runoff Program, BMPs designed to treat the first flush runoff in the Indianapolis area would treat the total runoff of up to 75% of the storms annually because the total storm depth of those storms is less than one inch.

The following equation is used to calculate WQ_v (in acre-feet):

$$WQ_v = \frac{(P)(R_v)(A)}{12} \qquad \text{(Equation 701.01)}$$

where:

WQ_v = water quality volume (acre-feet)
P = 1 inch of rainfall
R_v = 0.05 + 0.009(I) where I is the percent impervious cover
A = area in acres

Performance based BMPs whose design criteria have been pre-approved for use in the City of Indianapolis are traditional, structural, BMPs that have been in use around the country for several years. Structural BMPs that may be designed using performance based design criteria are discussed in detail in Section 702.

2. Proprietary Design
Innovative BMPs, for the purpose of this manual, are any BMPs that are not considered traditional structural BMPs for which performance based design standards are provided in Section 702. Examples of innovative BMPs would be manufactured BMPs such as hydrodynamic separation units, oil and floatable debris skimmers, and cartridge filter systems. All innovative BMPs must be professionally certified and approved through the New Product Committee. ASTM standard methods and / or City of Indianapolis approved testing methods must be followed when verifying performance of new measures.

The design process for an innovative BMP that is approved for use in the City of Indianapolis may be based on design flow capacity, on design volume, or other testing procedures approved by the City..

The process for applying for approval of innovative BMPs is described on the City of Indianapolis Department of Public Works website.

The following materials must be submitted in support of the application to approve a new BMP or process for use in the City of Indianapolis:

1. Narrative description of the practice or unit and its working principle(s).
2. Detailed description of the maintenance procedures.
3. Detailed drawings of the practice or unit.
4. Detailed description of the practice or unit's testing

[2] A periodic publication of the Center for Watershed Protection, Silver Springs, Maryland.

procedures.

5. Results of all tests.

The following performance criteria must be met by the proposed new BMPs. The BMPs:

1. Must meet the 80% TSS removal rate;
2. Must meet the floatable removal requirement;
3. May be required to reduce fecal bacteria;
4. May be required to control hydrocarbons or other land use-specific pollutants in stormwater runoff; and,
5. Must have a low to medium maintenance requirement to be considered by the City for use on public projects.

Testing to establish the TSS removal rate must be conducted by an independent testing facility, not the BMP manufacturer.

The most current list of pre-approved innovative / manufactured BMPs can be found on the DPW website. Go to www.indygov.org **and search for "stormwater design and construction specifications manual."**

701.05 Inspection and Maintenance

Each BMP (a single practice or combination of practices that meet the treatment goal) on a site must be identified in the operations and maintenance plan as specified in Section 102.06. The maintenance plan must be submitted with the stormwater management plan and approved by the City. The approved operations and maintenance plan must be provided to the BMP owner.

Annual inspections of permanent BMPs will be performed by the City. Prior to stormwater management plan approval, the developer or owner of a site must pay a predetermined fee to cover the City's costs for annual inspection for the first 3 years. The schedule of fees in Section 103.04 contains a set annual inspection cost. After the first 3 years, the City will inspect the facility and bill the owner. The number of BMPs on a site will be determined as follows; for each distinct drainage area that requires a stormwater quality control measure either a single BMP or a treatment train (system of 2 or 3 BMPs) will be required. Each BMP system treating a single drainage area is deemed to be one BMP for inspection purposes.

Routine inspections are the responsibility of the BMP owner. Maintenance is also the responsibility of the owner. The approved maintenance plan and inspection forms provided at the ends of each BMP section should be used as guidance for performing maintenance activities. Completed inspection forms must be maintained by the BMP owner and produced upon request by the City. The City must be notified of any changes in BMP ownership, major repairs or BMP failure in writing within 30 days. The letter should be addressed to :

Stormwater BMP Modifications
Department of Public Works
City-County Building

200 E. Washington, Suite 2460
Indianapolis, IN 46204

In the event that the City finds a BMP in need of maintenance or repair, the City will notify the BMP owner of the necessary maintenance or repairs and give the landowner a timeframe for completing the maintenance or repairs. If the maintenance or repairs are not completed within the designated timeframe, the City shall perform the repairs or maintenance and bill the landowner for the actual costs for the work.

SECTION 702 STRUCTURAL BEST MANAGEMENT PRACTICES

702.00 Structural Best Management Practices

Table 702-1 identifies pre-approved structural BMPs that can be used in Indianapolis for water quality control. The BMPs in this table are pre-approved for use if designed according to the criteria set forth in this chapter. Note that many of these measures can also be designed to meet the water quantity control requirements. Specific water quality design requirements are presented in the following sections.

Table 702-2 provides a summary of approved BMPs for different uses.

TABLE 702-01: Pre-Approved BMPs

BMP Type	Description	Quantity control	WQv and 80% TSS removal	Floatables Control	Bacteria Control
Stormwater Ponds • Wet pond • Wet extended detention pond • Micropool extended detention pond • Multiple pond systems	**Stormwater ponds are constructed stormwater detention basins with a permanent pool (or micropool) of water retained. Runoff from each rain event is captured and treated in the pool.**	**Yes**	**Yes**	**Yes**	**Yes***
Stormwater Wetlands • Shallow wetland • Extended detention wetland • Pond / wetland systems • Pocket wetland	**Stormwater wetlands are constructed, artificial wetland systems used for stormwater management. They consist of a combination of shallow marsh areas, open water and semi-wet areas above the permanent pool.**	**Yes**	**Yes**	**Yes**	**Yes***
Bioretention Areas	**Bioretention areas are shallow stormwater basins or landscaped areas that utilize engineered soils and vegetation to capture and treat stormwater runoff.**	**No**	**Yes**	**Yes**	**Yes**
Sand Filters • Surface sand filter • Perimeter sand filter	**Sand filters are multi-chamber structures designed to treat stormwater runoff through filtration, using a sand bed as its primary filter media.**	**No**	**Yes**	**Yes**	**Yes**
Water Quality Swales • Dry swale	**Water Quality swales are vegetated open channels that are designed and constructed to capture and treat stormwater runoff within dry cells.**	**No**	**Yes**	**No**	**No**
Biofilters • Filter strip • Grass channel	**While biofilters provide some filtering of stormwater runoff, by themselves they cannot meet the 80% TSS removal performance goal. *These measures can only be used as pre-treatment measures or as part of a treatment train.***	**No**	**No**	**No**	**Yes**
Catch Basin Inserts • Various designs	**Catch basin inserts are small filtering devices installed in each catch basin to trap suspended solids and other pollutants. Catch basin inserts must conform to the requirements noted in Section 702.09.**	**No**	**Yes**	**Yes**	**Yes**

* with waterfowl control

TABLE 702-02: BMP Selection Criteria

Current Use	Planned Use	Approved BMPs
Open land	Commercial strip, light industrial, institutional (individual lots)	Biorention, wet pond, artificial wetland, sand filters, biofilter, water quality swale, catch basin insert
Open land	Commercial or industrial subdivision (regional stormwater plan)	Wet pond, wetland
Open land	Residential	Bioretention, wet pond, artificial wetland, biofilter, water quality swale
Commercial building or strip (medium imperviousness)	Commercial building or strip	Bioretention, Sand filter, catch basin insert, wet pond, wetland
Commercial building or strip (small lot, high imperviousness)	Commercial building or strip	Bioretention, Sand filter, catch basin insert
Transportation infrastructure	Increased / expanded transportation infrastructure	Water quality swales, wet ponds, artificial wetlands, catch basin inserts

702.01 Stormwater Ponds

Wet detention ponds can be designed to meet both water quality and water quantity requirements. If the detention pond is to be designed for only water quality purposes, then the pond shall be designed to capture the water quality volumes as noted in Section 701.05. If the stormwater pond is to be designed for water quantity also, refer to Chapter 300.

Example schematics of stormwater ponds and variations can be found in Figures 702-3 through 702-6.

Site and Design Considerations

The following design and site considerations must be followed when designing a stormwater pond:

1. Design the pond with a minimum length to width ratio of 3:1 (preferably expanding outward toward the outlet), measured from the pond inlet to the pond outlet. Irregular shorelines for larger ponds provide visual variety. This length to width ratio must be met for each inlet to the pond.

2. Maximize flow length between the inlet and outlet structure. Use baffles if short-circuiting cannot be prevented with inlet-outlet placement. Long flow paths and irregular shapes are recommended.

3. When designing the BMP for the contributing drainage area, assume that the entire upstream watershed is fully developed. When

designing the BMP for the effective drainage area where offsite areas bypass the BMP, the design shall only consider the drainage from the site. Again, assume that the entire upstream watershed from the site is fully developed.

4. Provide a sediment forebay or other pretreatment upstream from the BMP inlet.
   - The forebay must be sized to contain 0.1 inches of runoff per impervious acre of contributing drainage. The forebay storage volume counts toward the total water quality storage requirements.
   - Exit velocities from the forebay must be non-erosive.
   - Direct maintenance access for appropriate equipment must be provided to the forebay.
   - The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
   - A fixed vertical sediment depth marker must be installed in the forebay to measure sediment deposition over time.
   - Sediment removal in forebay shall occur when 50% of the total capacity has been lost.

5. Side slopes shall be no greater than 3:1 if mowed.

6. Rip-rap protection must be provided (or other suitable erosion control means) for the outlet and all inlet structures into the pond.

7. A wet stormwater pond is characterized by a permanent wet pool. The designer must evaluate both the soils and the hydrology of the site to insure that the pond will maintain a permanent wet pool. (Note: Chapter 300 allows dry detention ponds, however, little water quality benefit is provided from dry detention ponds.)

8. Anti-seep collars or filter diaphragms must be provided for the barrel of principal spillway.

9. If reinforced concrete pipe is used for the principal spillway, O-ring gaskets (ASTM C361) shall be used to create watertight joints.

10. Provide a one (1) foot minimum freeboard above the maximum anticipated flow depth through the emergency spillway.

11. Design and install an emergency drain (i.e. sluice gate or drawdown pipe) capable of draining within 24 hours. Where topographical limitations prevent the use of a sluice gate or drawdown pipe, the design should indicate a pump may need to be used to draw down the pond and the pump rate specified to meet the 24-hr drawdown period.

12. Emergency spillway designed to pass 1.25 times the peak <u>inlet</u> flow rate and peak flow velocity from the 100-year storm event for the entire contributing drainage area (unless bypassed), assuming post-development conditions (see Section 302.08).

13. Provide trash racks, filters, hoods or other debris control. The debris control should meet the minimum floatable capture requirements.

14. Regional facilities must be constructed within a stormwater easement either platted or legally described and recorded as a perpetual stormwater easement a minimum of 20 feet horizontally outside of the design 100-year flood water elevation of the basin. Provide a 10’ foot wide permanent access easement for all local ponds for long-term maintenance.

15. Provide a permanent benchmark within the permanent pool and sediment forebay for sediment removal.

16. The principal spillway/riser system must incorporate anti-floatation, anti-vortex, and trash-rack designs.

17. To prevent drawdown of the permanent pool, an impervious soil boundary may be needed.

18. Orifice-type outlets are not allowed below the permanent pool elevation of wet ponds and micropools.

19. If orifices are utilized for drawdown purposes for stages above the permanent pool the orifices are to be protected against clogging by use of screening or other means. If the outlet diameter is larger than 2 inches then the minimum orifice diameter allowed is 2 inches.

20. Construction debris cannot be disposed of within the facility or used as fill in the embankment.

21. The BMP must be located within an easement. The easement must include access to the BMP for maintenance. A copy of the easement should be included in the digital copy of the BMP operations and maintenance manual.

22. If the pond is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the pond and elevations and grades have been reestablished as noted in the approved stormwater management plan for post-construction runoff control.

23. Tall plantings in the aquatic bench are desirable as a means to keep waterfowl from the site. Waterfowl are bacteria sources and are to be discouraged from inhabiting wet ponds. Long, narrow, irregularly shaped ponds with tall plantings are encouraged in order to minimize attractiveness of the pond to waterfowl.

Performance Standards

Wet ponds and variations designed, constructed and maintained as noted above provide the following pollutant reductions:

Pollutant	Percent reduction
TSS	85%

Bacteria	65%
BOD	30%
Total P	50%
Total N	30%
Metals	30%

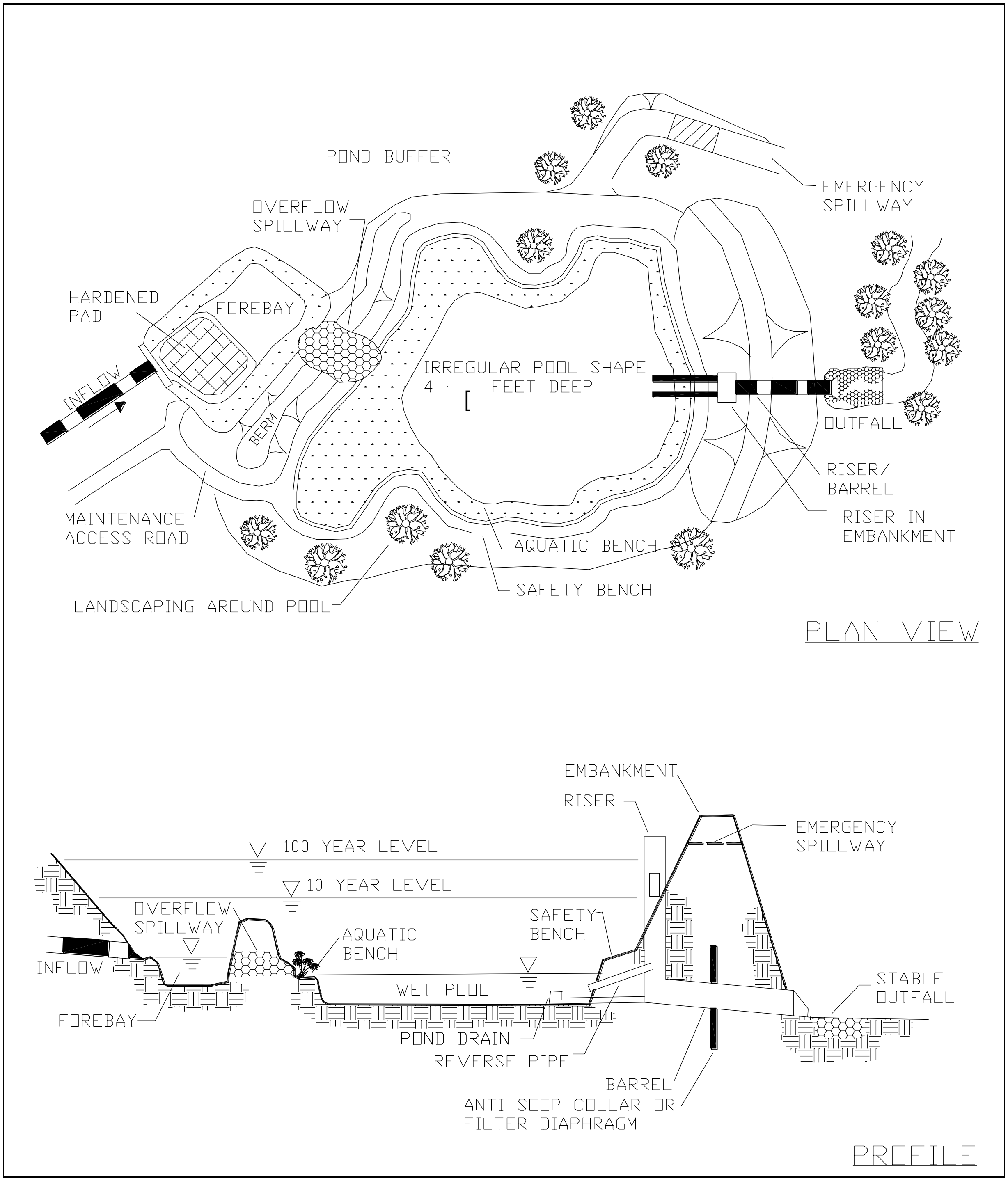

FIGURE 702-01: Wet Pond

Variations

- **Wet extended detention ponds**: A wet extended detention pond is a wet pond where the water quality volume is split evenly between the permanent pool and the extended detention storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 12 - 48 hours. This design has similar pollutant removal to a traditional wet pond, but consumes less space.

- **Micropool extended detention pond**: The micropool extended detention pond is a variation of the wet extended detention pond where only a small micropool is maintained at the outlet to the pond. The outlet is sized to detain the water quality volume for 24 hours. The micropool prevents resuspension of previously settled sediments.

- **Multiple pond systems**: Multiple pond systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection.

Advantages

1. High pollutant removal

2. High community acceptance, if designed and maintained correctly

3. Opportunity for wildlife habitat

4. Multi-objective use for water quality and quantity control

Disadvantages

1. Potential for thermal impacts downstream

2. Dam height restrictions

3. Attractive to waterfowl, resulting in bacteria increases, unless shape and vegetation discourage waterfowl

Maintenance

Refer to the checklist provided in Figure 702-7 for operation, maintenance and inspection of stormwater ponds. The checklist is for the use of the BMP owner in performing routine inspections. The City will perform annual inspections of BMPs, using a similar checklist. The developer/owner is responsible for the cost of maintenance and annual inspections. See Section 103.04 for a schedule of fees. The BMP owner must maintain and update the BMP operations and maintenance plan. At a minimum, the operations and maintenance plan must include , but is not limited to:

1. Removal debris from inlet and outlet structures

2. Removal of invasive vegetation from all side slopes

3. Removal of sediment accumulation from forebay and permanent pool area when 50% full

4. Removal of woody vegetation from the embankment

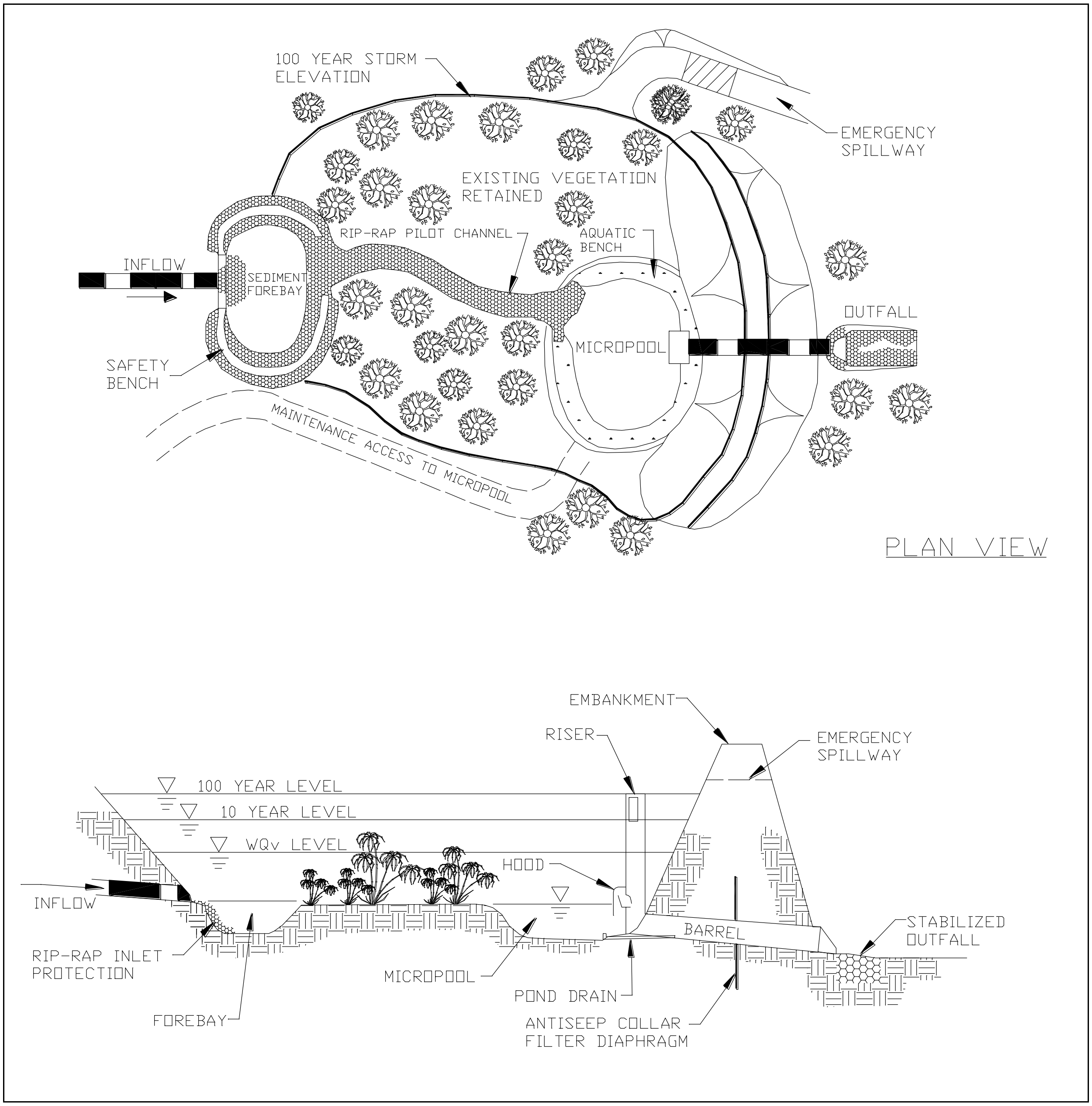

FIGURE 702-03: Micropool Extended Detention Pond

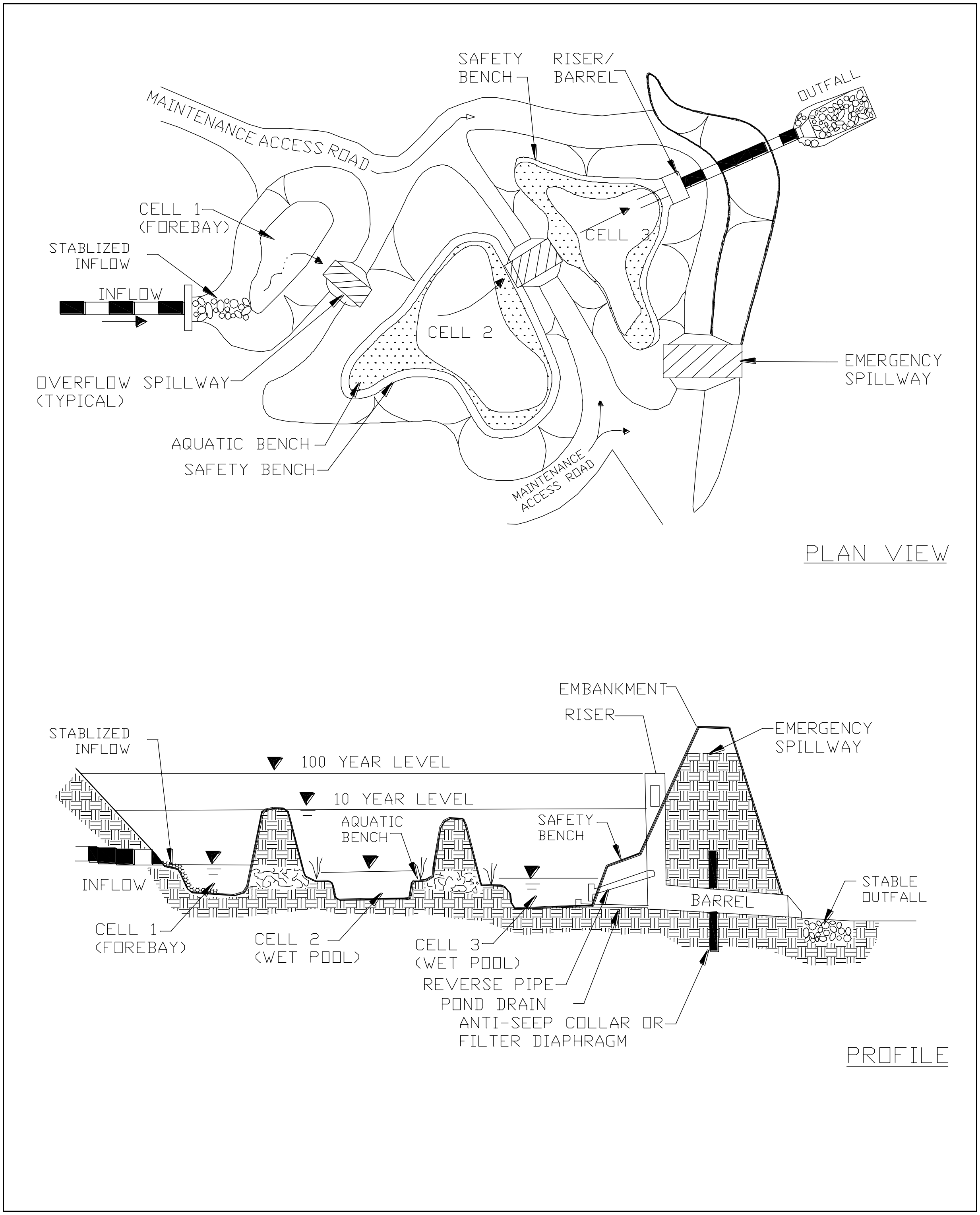

FIGURE 702-04: Multiple Pond System

Stormwater Pond Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Project: ______________________________ Owner Change since last inspection? Y N

Owner Name, Address, Phone ______________________________

Number______________________________

Location: ______________________________

Site Status: ___

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Embankment and Emergency Spillway (Inspect annually and after major storms)		
1. Vegetation		
2. Erosion on embankment		
3. Animal burrows		
4. Cracking, bulging or sliding of dam		
A. Location:		
B. Describe		
5. Drains clear and functioning		
6. Leaks or seeps on embankment		
A. Location		
B. Describe		
7. Slope protection failure		
8. Emergency spillway clear of obstructions		
9. Other (describe)		

FIGURE 702-05: Private Operation, Maintenance & Management – Stormwater Ponds

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Riser and Principal spillway (Inspect annually)		
Circle Type: Reinforced concrete, corrugated pipe, masonry		
1. Low flow orifice blocked		
2. Trash rack		
A. debris removal needed		
B. corrosion noted		
3. Excessive sediment buildup in riser		
4. Concrete/Masonry condition		
A. cracks or displacement		
B. spalling		
5. Metal pipe condition		
6. Control Valve operational		
7. Pond drain valve operational		
8. Outfall channels functioning		
9. Other (describe)		
Permanent Pool (Inspect monthly)		
1. Undesirable vegetative growth		
2. Floatable debris removal needed		
3. Visible pollution		
4. Shoreline problem		
5. Other (describe)		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Sediment Forebays		
1. Sedimentation noted		
2. Sediment cleanout needed (over 50% full)		
Other (Inspect monthly)		
1. Erosion at outfalls into pond		
2. Headwalls and endwalls		
3. Encroachment into pond or easement area		
4. Complaints from residents		
5. Public hazards (describe)		

Additional Comments

Actions to be taken: **Timeframe:**

702.02 Stormwater Wetlands

Stormwater wetlands are artificial wetlands created for the purposes of stormwater pollutant removal and quantity control. It is the intent of the City and County to encourage regional stormwater wetlands and discourage artificial wetlands designed for individual sites. However, BMP plans will be reviewed on a case-by-case situation to determine feasibility.

Refer to figure 702-8 through 702-11 for schematics of stormwater wetlands. Figure 702-12 represents a cross-sectional view through the outlet system. Note: The waterfowl island in Figure 702-9 is an optional feature.

Site and Design Considerations

Prior to stormwater management plan approval, the following design and site considerations must be followed:

1. A water balance must be performed to demonstrate that a stormwater wetland could withstand a thirty-day drought at summer evaporation rates without completely drawing down. Also, inflow of water must be greater than that leaving the basin by infiltration or exfiltration. The following water balance equation should be used in calculations:

   S = Qi + R + Inf - Qo – ET

   Where:
   S = net change in storage
   Qi = stormwater runoff inflow
   R = contribution from rainfall
   Inf = net infiltration (infiltration – exfiltration)
   Qo = surface outflow
   ET = evapotranspiration
2. The wetland must be designed for an extended detention time of 48 hours for the WQ_v. The orifices used for extended detention will be vulnerable to blockage from plant material or other debris that will enter the basin with stormwater runoff. Therefore, some form of protection against blockage must be installed (such as some type of non-corrodible wire mesh or a stone-protected filter fabric).
3. The minimum orifice size allowable will be 2 inches for the outlet control structure.
4. The frequently flooded zone surrounding the wetland must be located within the permanent easement.
5. The surface area of the wetland must account for a minimum of 1 percent of the area of the watershed draining into it (1.5 percent for a shallow marsh design). The length to width ration must be at least 2:1.
6. The design must incorporate long flow paths through the wetland, as appropriate.
7. A forebay shall be established at the pond inflow points to capture larger sediments and be 4 to 6 feet deep. The forebay area should be such that the forebay contains approximately 10 percent of the total volume of the normal pool. Direct maintenance access to the forebay must be provided with access 25 feet wide minimum and 5:1 slope maximum. Permanent sediment depth markers must be provided.

8. If high water velocity is a potential problem, some type of energy dissipation device must be installed.
9. Site preparation: Soil types conducive to wetland vegetation should be used during construction. A list of hydric soils, developed by the NRCS, can be found in Appendix B7. The wetland must be designed to allow slow percolation of the runoff through the substrate (add a layer of clay for porous substrates). Ensure that the substrate, once flooded, is soft enough to permit relatively easy insertion of the plants.
10. Planting: The designer must maximize use of existing- and post-grading pondscaping design to create both horizontal and vertical diversity and habitat. A minimum of 2 aggressive wetland species of vegetation shall be established in quantity on the wetland. Three additional wetland species of vegetation shall be planted on the wetland, although in far less numbers than the two primary species. 30 to 50 percent of the shallow (12 inches or less) area of the basin shall be planted with wetland vegetation. The optimal depth requirements for several common species of emergent wetland plants are often six inches of water or less. Approximately 50 individuals of each secondary species must be planted per acre; set out in 10 clumps of approximately 5 individuals and planted within 6 feet of the edge of the pond in the shallow area leading up to the ponds edge; spaced as far apart as possible, but no need to segregate species to different areas of the wetland. Wetland mulch, if used, shall be spread over the high marsh area and adjacent wet zones (-6 to +6 inches of depth) to depths of 3 to 6 inches. A minimum 25 foot buffer, for all but pocket wetlands, must be established and planted with riparian and upland vegetation (50 foot buffer if wildlife habitat value required in design). In addition, the wetland must be located within a 40-foot wide easement. A list of wetland species indigenous to and commercially available in Indiana can be found in Appendix C7.
11. If the wetland area or sediment forebay is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the wetland or forebay and elevations and grades have been reestablished as noted in the approved stormwater management plan for post-construction runoff control.
12. Stormwater wetlands must be designed with the recommended proportion of depths noted in Table 702-3. The four basic depths and descriptions are:
13. Surrounding slopes must be stabilized by planting to aid in trapping pollutants and preventing them from entering the wetland.
14. Maintain the wetland to prevent loss of the area of ponded water available for emergent vegetation due to sedimentation and/or accumulation of plant material.
15. Obtain local assistance for specifications on plants to be used, planting schedule, soil requirements, mulch requirements, etc.
16. Tall plantings are desirable as a means to keep waterfowl from the site. Waterfowl are bacteria sources and should be discouraged from inhabiting stormwater wetlands to the extent possible. Long, narrow, irregularly shaped micropools with tall plantings along the perimeter are encouraged in order to minimize attractiveness of the facility to waterfowl.

17. Construction debris cannot be disposed of in the facility or used as fill in the embankment.
    - *Deepwater:* 1.5 feet or more below normal pool elevation. Includes the outlet micropool and deep water channels through the wetland. This zone supports little emergent wetland vegetation but may support floating or submerged vegetation.
    - *Low marsh:* 6-18 inches below normal pool elevation or water surface elevation. This zone is suitable for the growth of several emergent wetland species.
    - *High marsh:* 6 inches or less below normal pool elevation. This zone will support a greater density and diversity of wetland vegetation than the low marsh. The high marsh area should have a greater surface area to volume ration than the low marsh area.
    - *Semi-wet zone:* Areas above normal pool elevation inundated by larger storm events. This area supports vegetation that can survive periodic flooding.

TABLE 702-03: Minimum Required Design Configuration for Stormwater Wetlands

Design Criteria	Shallow Wetland	Pond/Wetland	Pocket Wetland
Length to width ratio (min)	2:1	2:1	2:1
Allocation of WQv (pool/marsh) in %	25/75	70/30 (includes pond volume)	25/70
Allocation of surface area (deepwater/low marsh/high marsh/semi-wet) in %	20/35/40/5	45/25/25/5 (includes pond surface area)	10/45/40/5
Forebay	Required	Required	Required
Micropool	Required	Required	Required
Outlet configuration	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Hooded broad crest weir

Modified from Massachusetts DEP, 1997; Schueler, 1992

Performance Standards

Artificial wetlands designed, constructed and maintained as noted above provide the following pollutant reductions:

Pollutant	Percent Reduction
TSS	95%
Bacteria	95%
BOD	55%
Total P	55%
Total N	45%
Metals	80%

Operation and Maintenance Recommendations

Each BMP must have an operations and maintenance plan submitted to the City for approval and maintained and updated by the BMP owner. Refer to Figure 702-13 for a checklist for routine operation, inspection and maintenance requirements for the BMP owner. The City will perform annual inspections, with a similar checklist. The BMP owner is responsible for the cost of maintenance and annual inspections. See Section 103.04 for the schedule of costs.

1. A stormwater management easement and maintenance agreement is required for each facility. The maintenance covenant must require the owner of the wetland to annually clean the facility and outlet structure. The maintenance agreement must provide for ongoing inspection and maintenance, with more intense activity for the first three years after construction. The easement must include the BMP, all outlet structures and access to the BMP. A copy of the easement should be included in the digital copy of the BMP operations and maintenance manual.

2. The wetland must be maintained to prevent loss of area of ponded water available for emergent vegetation due to sedimentation and/or accumulation of plant material.

3. Sediment forebays must be cleaned when 50% full. Pocket wetlands without forebays must be cleaned after a six-inch accumulation of sediment.

4. The ponded water area may be maintained by raising the elevation

of the water level in the permanent pond, by raising the height of the orifice in the outlet structure, or by removing accumulated solids by excavation.

5. Water levels may need to be supplemented or drained periodically until vegetation is fully established.

6. It may be desirable to remove contaminated sediment bottoms or to harvest above ground biomass and remove it from the site to permanently remove pollutants from the wetland.

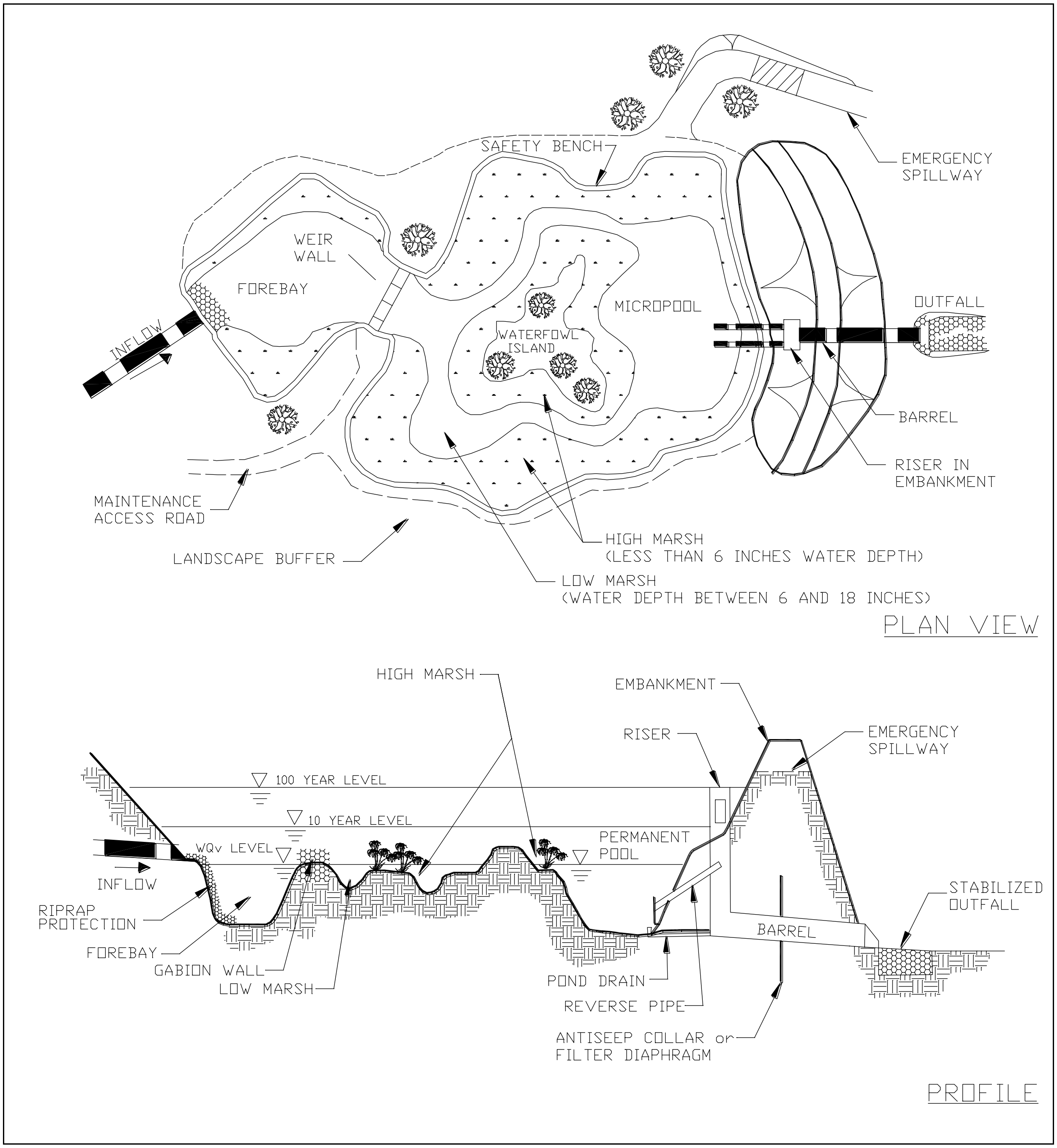

FIGURE 702-07: Shallow Wetland
Courtesy of the Center for Watershed Protection

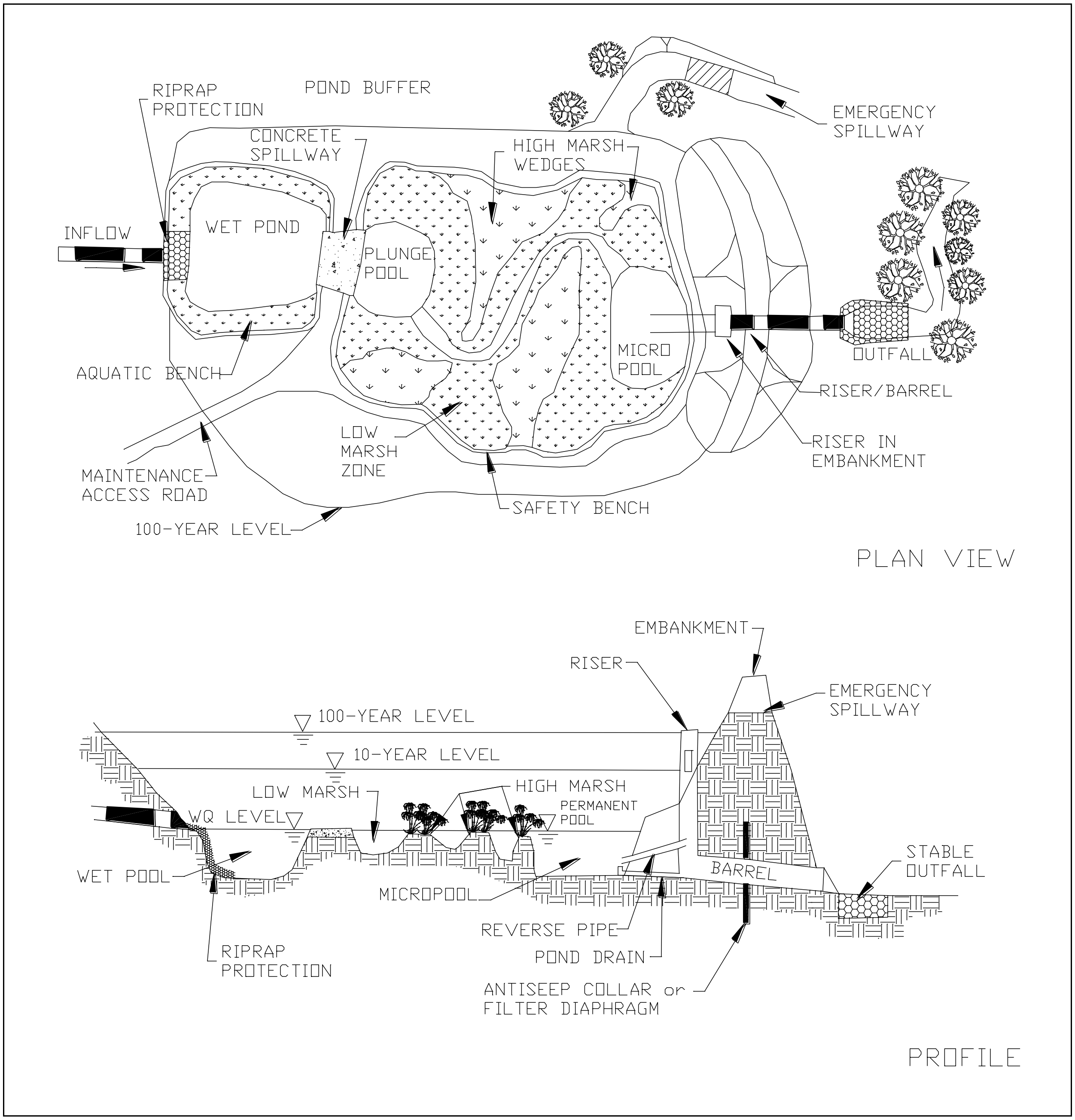

FIGURE 702-08: Schematic for a Pond/Wetland System
Courtesy of the Center for Watershed Protection

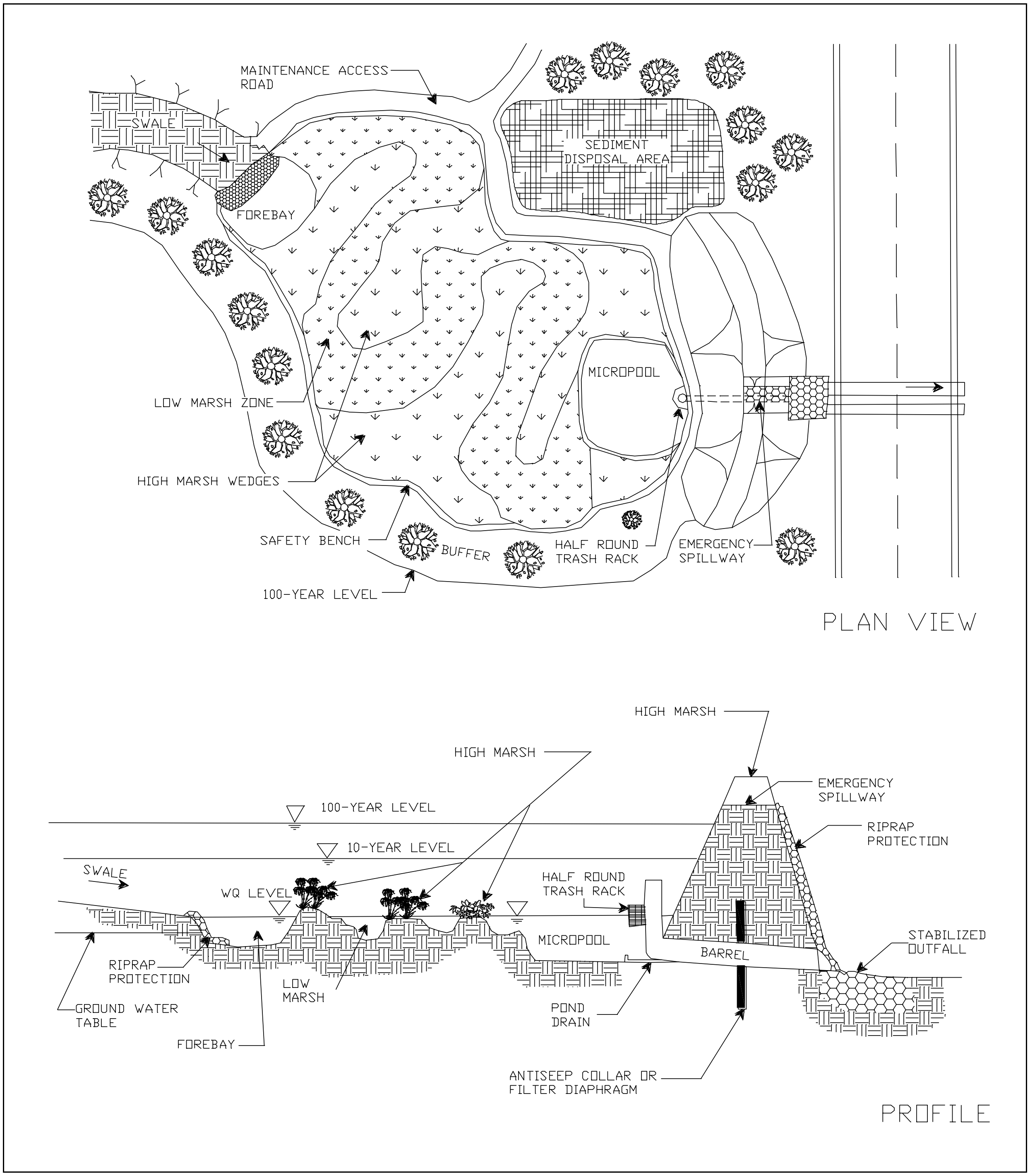

FIGURE 702-09: Schematic of a Pocket Wetland
Courtesy of the Center for Watershed Protection

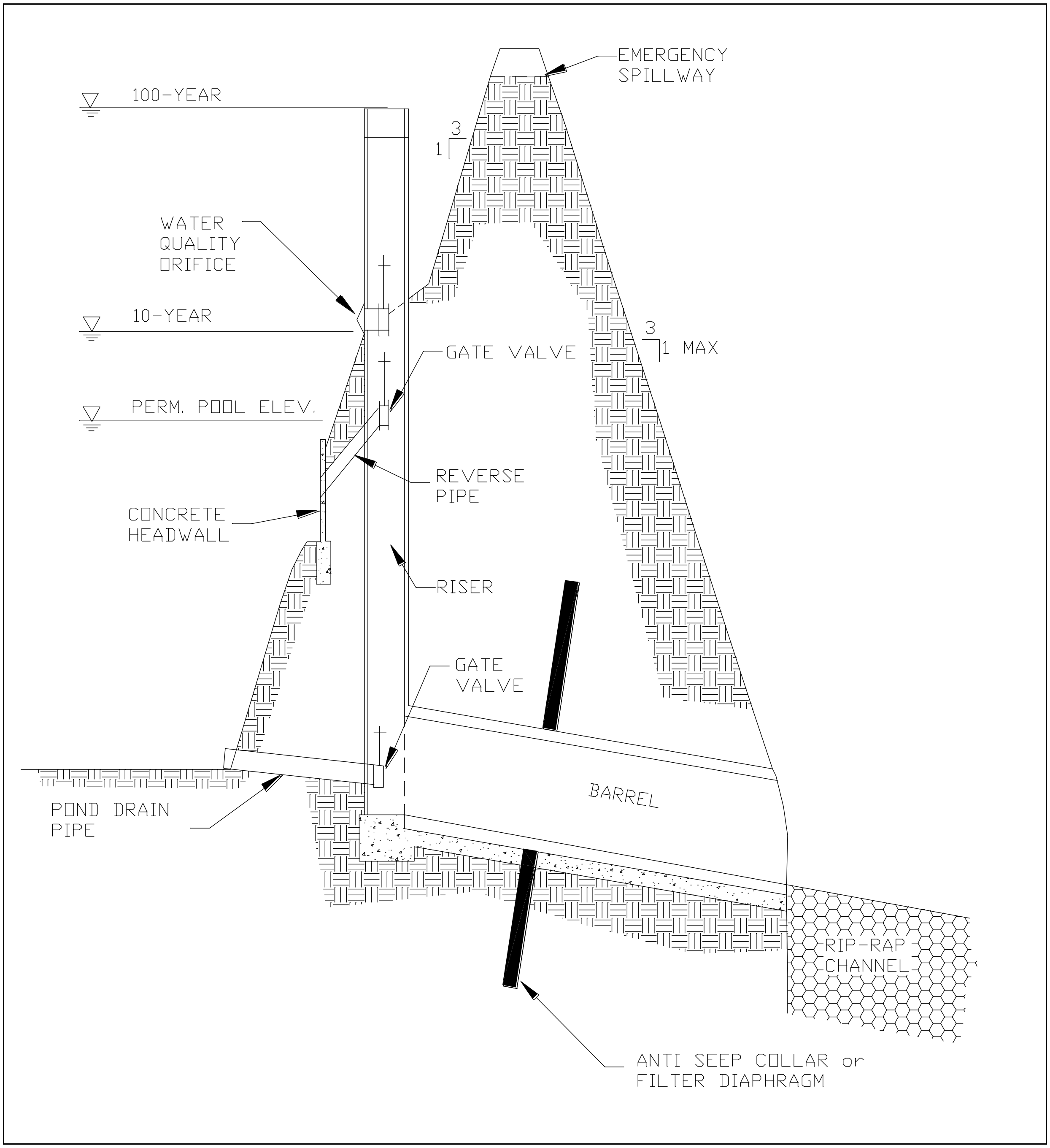

FIGURE 702-10: Schematic of Outlet System

Constructed Wetlands Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Site Name: ____Owner changed since last inspection? Y N

Owner name, address, phone number: ____

Location: ____

Date: ____

Time: ____

Inspector Name: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Embankment and Emergency Spillway (Inspect annually and after major storms)		
1. Vegetation		
2. Erosion on embankment		
3. Animal burrows		
4. Cracking, bulging or sliding of dam		
A. Location:		
B. Describe		
5. Drains clear and functioning		
6. Leaks or seeps on embankment		
A. Location		
B. Describe		
7. Slope protection failure		
8. Emergency spillway clear of obstructions		
9. Other (describe)		

FIGURE 702-11: Private Operation, Maintenance & Management – Constructed Wetlands

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Riser and Principal spillway (Inspect annually)		
Circle Type: Reinforced concrete, corrugated pipe, masonry		
1. Low flow orifice blocked		
2. Trash rack		
A. debris removal needed		
B. Corrosion noted		
3. Excessive sediment buildup in riser		
4. Concrete/Masonry condition		
A. cracks or displacement		
B. spalling		
5. Metal pipe condition		
6. Control Valve operational		
7. Pond drain valve operational		
8. Outfall channels functioning		
9. Other (describe)		
Permanent Pool (Inspect monthly)		
1. Undesirable vegetative growth		
2. Floatable debris removal needed		
3. Visible pollution		
4. Shoreline problem		
5. Other (describe)		
Sediment Forebays		

1. Sedimentation noted		
Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
2. Sediment cleanout needed (over 50% full)		
Other (Inspect monthly)		
1. Erosion at outfalls		
2. Headwalls and endwalls		
3. Encroachment into easement area		
4. Complaints from residents		
5. Public hazards (describe)		
Constructed Wetland Area (Inspect annually)		
1. Vegetation healthy and growing		
2. Evidence of invasive species		
4. Excessive sediment in wetland area (clean out when 50% full or when vegetation damage noted)		

Additional Comments

Actions to be taken: **Timeframe:**

702.03 Bioretention

Bioretention (702.03), micro-bioretention (702.03a) and rain garden (702.03b) areas, are structural stormwater controls that capture and temporarily store the WQ_v using soils and vegetation in landscaped areas to remove pollutants from stormwater runoff.

- Bioretention: Intended use for drainage areas 5 acres or less, however if hydraulic and hydrologic design criteria are met, sites may be designed to manage multiple 5 acre watersheds.
  - When designed according to the guidance below, bioretention practices will provide treatment for the required WQ_v.

- Micro-bioretention: Intended to be versatile and can be adapted for use anywhere there is landscaping. Contributing drainage area < 20,000 ft^2
  - When designed according to the guidance below, micro-bioretention practices will provide treatment for the required WQ_v. Post-development CN's for impervious areas treated using micro-bioretention practices may be assumed to be "open space in good condition" when computing Q_v requirements.

- Rain garden: Typically used to treat runoff from small impervious areas like rooftops, driveways, and sidewalks. Rain gardens can also be used in retrofitting and redevelopment applications and in series where existing slopes require energy dissipation. Contributing drainage area < 10,000ft^2.
  - When designed according to the guidance below, the contributing impervious area may be subtracted from total impervious cover when calculating WQ_v. Post development CN's for areas served by rain gardens may be assumed to be "open space in good condition" when computing Qv.

Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," consisting of a pretreament area, including a sediment forebay, ponding area containing vegetation with a planting soil bed, organic/mulch layer and gravel and perforated pipe underdrain system. The filtered runoff is typically collected and returned to the conveyance system, though it can be infiltrated into the in-situ soils in areas with porous soils (>1"/hour), though infiltration may not be permitted in Wellfield Zoning Districts or hotspot locations. If no perforated pipe underdrain system is used, a geotechnical investigation, soil infiltration testing, and a hotspot investigation must be completed.

Bioretention facilities can provide a limited amount of water quantity control, with the storage provided by the facility included in the design of any downstream detention structures.

Bioretention areas are designed for intermittent flow and to drain and aerate between rainfall events. Sites with continuous flow from groundwater, sump pumps or other areas must be avoided.

Figure 702-14 illustrates a typical detail of a bioretention area. Bioretention areas consist of:

1. Grass filter strip between the contributing drainage area and the ponding area;

2. Ponding areas containing vegetation with a planting soil bed,

3. Organic/mulch layer, and

4. Gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil).

1. Pretreatment, including a sediment forebay between the contributing drainage area and the ponding area;

2. Ponding areas containing vegetation with a planting soil bed,

3. Organic/mulch layer, and

4. Gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil).

Design components should include:
   1. Energy dissipation to reduce velocities and spread flow into the bioretention ponding area.
   2. Inflow diversion or an overflow structure to carry flows greater than designed hydrologic capacity.

Site and Design Considerations
The following design and site considerations must be incorporated into the BMP plan including bioretention areas:

1. The drainage area (contributing or effective) must be 5 acres or less, though 0.5 to 2 acres is preferred. Alternative designs can vary by location but NOT hydraulic/hydrologic design considerations.

2. The minimum size for facility is 200 ft^2, with a length to width ratio of 2:1. Slope of the site can be no more than 6%.

3. Planting soil filter bed is sized using a Darcy’s Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day. The planting soil bed must be at least 2 feet deep. Planting soils must be sandy loam, loamy sand or loam texture with a clay content rating from 10 to 25 percent. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil should have a 1.5 to 3 percent organic content and a maximum 500-ppm concentration of soluble salts.

4. The maximum ponding depth in bioretention areas is 24 inches.

5. Pretreatment, including forebay, design for pre-treatment must follow the requirements outlined in Section 702.06.

6. The mulch layer must consist of 2-4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.

7. The underdrain collection system must be equipped with a 6 inch perforated PVC pipe in an 8-inch gravel layer. The pipe must have 3/8-inch perforations, spaced on 6-inch centers with a minimum of 4 holes per row, or equivalent. The pipe is spaced at a maximum of 10 feet on center, and a minimum grade of 0.5% must be maintained. A permeable filter fabric or a gravel lens (3/4-1/4 inch, crushed rock 2 to 3 inches deep), is placed between the gravel layer and the planting soil bed.

8. The depth from the bottom of the bioretention facility to the documented seasonally high water table must be a minimum of 2 feet. The seasonal high water table must be field determined by a soil scientist or geo-technical investigation.

9. Runoff captured by facility must have energy dissipation to prevent erosion of the organic or mulch layer. Velocities entering the mulch layer must be less than or equal to 1.5 ft/s.

10. Continuous flow from groundwater, sump pumps or other areas to the bioretention area is not recommended and will be reviewed on a case by case condition.

11. An overflow structure and a non-erosive overflow channel must be provided to safely pass the flow from the bioretention area that exceeds the storage capacity to a stabilized downstream area.

12. All components of the BMP must be located within an easement. Access to the BMP must be located within the easement.

13. If the bioretention area is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the bioretention area and elevations and grades have been reestablished as noted in the approved stormwater management plan for post-construction runoff control.

Performance Standards

Bioretention areas designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Pollutant	Percent Reduction

TSS	81%
Bacteria	90%
Total P	29 %
Total N	49 %
Metals	61 %

Advantages
1. Applicable to drainage areas <5 acres
2. Often located in landscape islands
3. High pollutant removal
4. High community acceptance, if designed and maintained correctly

Disadvantages
1. Requires extensive landscaping
2. Not recommended for areas with steep slopes

Maintenance

A BMP operations and maintenance plan is required for bioretention facilities. The plan must be approved by the City and maintained and updated by the BMP owner. Refer to Figure 702-15 for a checklist for BMP owners for the routine operation, maintenance and inspection of bioretention areas. The City will perform annual BMP inspections, using a similar checklist. The BMP owner is responsible for maintenance costs and inspection fees. See Section 103.04 for the schedule of fees.

1. Inspect and repair/replace treatment components.

Landscaping

Landscaping is critical to the performance and function of the bioretention area. A dense and vigorous groundcover must be established over the contributing pervious drainage area before runoff can be diverted into the facility.

1. The bioretention area should be vegetated like a terrestrial forest ecosystem, with a mature tree canopy, subcanopy of understory trees, scrub layer and herbaceous ground cover. Three species of each tree and shrub type should be planted.

2. Perennials, grass-like plants, and ground-cover plants shall be healthy, well-rooted specimens. Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

   The following quantities per 100 square feet of bioretention area are suggested:

   • 1 large tree per 100 square feet of bioretention area

• 2-4 small trees or shrubs per 100 square feet of bioretention area
• 6 ferns or grass-like plants per 100 square feet of bioretention area (1-gallon containers)
• Groundcover plantings and wildflower plugs on 12 inch centers with triangular spacing.
•A native grass/wildflower seed mix can be used as an alternative to groundcover planting.

3. .Woody vegetation should not be planted at inflow locations or near subsurface drainage pipes.

4. After the trees and shrubs are established, the ground cover and mulch should be established.

5. Use native plants, selected based upon hardiness and hydric tolerance.

6. Landscaping plans shall be provided according to the guidance provided by DPW and DMD.

702.03a Micro-Bioretention

Micro-bioretention practices capture and treat runoff from discrete impervious areas by passing it through a filter bed mixture of sand, soil, and organic matter. Filtered stormwater is either returned to the conveyance system or partially infiltrated into the soil. Micro-bioretention practices are versatile and may be adapted for use anywhere there is landscaping.

Applications:

Micro-bioretention is a multi-functional practice that can be easily adapted for new and redevelopment applications in commercial and industrial projects. Stormwater runoff is stored temporarily and filtered in landscaped facilities shaped to take runoff from various sized impervious areas. Micro-bioretention provides water quality treatment, aesthetic value, and can be applied as concave parking lot islands, linear roadway or median filters, terraces slope facilities, residential cul-de-sac islands, and ultra-urban planter boxes.

Performance:

When designed according to the guidance below, micro-bioretention practices will provide treatment for the required WQ_v. Post-development CN's for impervious areas treated using micro-bioretention practices may be assumed to be "open space in good condition" when computing Q_v requirements.

Constraints:

The following constraints are critical when considering the use of micro-bioretention to capture and treat stormwater runoff:

- **Space:** The surface area of a typical micro-bioretention filter is dependent on the area of the contributing imperviousness. The size and distribution of open areas within a project (e.g., parking lot islands, landscaped areas) must be considered early during a project's planning and design if these practices are considered.

- **Topography:** Slopes of contributing areas and filter beds should be gradual (<5%). If slopes are too steep, then level-spreading devices may be needed to redistribute flow prior to filtering. If slopes within micro-bioretention practices are too steep, then a series of check dams, terraces, or berms may be needed to maintain sheetflow internally.

There should also be an elevation difference between the inflow and outflow of a micro- bioretention practice to allow flow through the filter. This difference is critical when designing downstream conveyance systems (e.g., grass channels, storm drains).

- **Soils:** Soil conditions are a crucial determining factor for micro-bioretention because specific applications will be affected. When located in sandier soils, these practices may be used to promote infiltration. If clayey soils are encountered, an underdrain system may be needed to convey water downstream. Also, elevated groundwater may limit filter bed thickness and excavated applications.

Subsurface water conditions (e.g., water table) will help determine the thickness of filter beds used. The probability of practice failure increases if the filter bed intercepts groundwater. Therefore, micro-bioretention practice inverts should be above local groundwater tables.

- **Drainage Area:** The drainage area to micro-bioretention practices should be limited. As the impervious area draining to each practice exceeds ½ acre, practice effectiveness weakens and larger systems designed according to Bioretention 702.03 should be considered.

- **Hotspot Runoff:** Micro-bioretention practices that are designed to promote infiltration of runoff into the ground should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.

- **Infrastructure:** The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer, storm drains, electricity) will influence the design and construction of micro-bioretention. Landscape designers should also consider overhead electrical and telecommunication lines when selecting trees to be planted.

Design Guidance:

The following conditions should be considered when designing micro-bioretention practices.

- **Conveyance:** Micro-bioretention systems should be designed off-line whenever possible. A flow splitter should be used to divert excess runoff away from the filter media to a stable, downstream conveyance system. If by passing a micro-bioretention practice is impractical, an internal overflow device (e.g., elevated yard inlet) may be used.

Runoff shall enter, flow through, and exit micro-bioretention practices in a safe and non-erosive manner. Inflow may be through depressed curbs with wheel stops, curb cuts, or conveyed directly using downspouts, covered drains, or catch basins. Depending on site layout and the size and shape of the impervious area being treated, overflow structures should be located to maximize internal flow paths through the filter media. An underdrain system may be necessary to discharge treated stormwater safely downstream. Underdrains may be interconnected to other micro-scale practices as part of a treatment system or directly to the storm drain.

- **Treatment:** Micro-bioretention practices shall meet the following conditions:
  - The drainage area to any individual practice shall be 20,000 ft^2 or less.
  - Micro-bioretention practices shall capture and store the WQ_v.
  - The filter bed surface area (ft^2) shall be at least 10% of the impervious drainage area and the surface ponding depth 24 inches or less.
  - Filter beds should be a minimum of 24 inches deep.
  - Filter beds should not intercept groundwater. If designed as infiltration practices, filter bed inverts shall be separated at two feet from the documented seasonal high water table.
  - A surface mulch layer (maximum 2 to 3 inches thick) should be provided to enhance plant survival and inhibit weed growth.
  - The filtering media, mulch, and underdrain systems shall conform to the specifications found in Green Infrastructure Supplemental document.

- **Setbacks:**
  - Micro-bioretention practices should be located down gradient and setback at least 10 feet from structures. Micro-bioretention variants (e.g., planter boxes) that must be located adjacent to structures should include an impermeable liner.
  - Micro-bioretention practices shall be located at least 30 feet from water supply wells and 25 feet from septic systems. If designed to infiltrate, then the practice shall be located at least 50 feet from confined water supply wells and 100 feet from unconfined water supply wells.
  - Micro-bioretention practices should be sized and located to meet minimum local requirements for clearance from underground utilities.
  - Any trees planted in micro-bioretention practices shall be

located to avoid future problems with overhead electrical and telecommunication lines.

- **Landscaping:** Vegetation is critical to the function and appearance of any micro-bioretention system. Therefore, landscaping plans shall be provided according to the guidance in Green Infrastructure Supplemental document. Native and adapted plants are preferred, hardier, and usually require minimal nutrient or pesticide application. Also, aesthetically pleasing landscape designs generally enhance property value and community acceptance.

Construction Criteria:

The following items should be addressed during construction of projects with micro-bioretention:

- **Erosion and Sediment Control:** Micro-bioretention practices should not be constructed until the contributing drainage area is stabilized. If this is impractical, runoff from distributed areas should be diverted away and no sediment control practices should be used near the proposed location.

- **Soil Compaction:** Excavation should be conducted in dry conditions with equipment located outside of the practice to minimize bottom and sidewall compaction. Only lightweight, low ground-contact equipment should be used within micro-bioretention practices and the bottom scarified before installing underdrains and filtering media.

- **Underdrain Installation:** Gravel for the underdrain system should be clean, washed, and free of fines. Underdrain pipe should be checked to ensure that both the material and perforations meet specifications. The upstream ends of the underdrain pipe should be capped prior to installation

- **Filter Media Installation:** Bioretention soils may be mixed on-site before placement. However, soils should not be placed under saturated conditions. The filter media should be placed and graded using excavators or backhoes operating adjacent to the practice and be placed in horizontal layers (12 inches per lift maximum). Proper compaction of the media will occur naturally. Spraying or sprinkling water on each lift until saturated may quicken settling times.

- **Landscape Installation:** The optimum planting time is during the autumn months. Spring planting is also acceptable but may require watering.

Inspection:

- Regular inspections shall be made during the following stages of construction:

    - During excavation to subgrade and placement and

backfill of underdrain systems.
  - During placement of filter media.
  - During construction of appurtenant conveyance.
  - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of micro-bioretention practices:

- The top few inches of filter media should be removed and replaced when water ponds for more than 24 hours. Silts and sediment should be removed from the surface of the filter bed when accumulation exceeds one inch.
- Where practices are used to treat areas with higher concentrations of heavy metals (e.g., parking lots, roads), mulch should be replaced annually. Otherwise, the top two to three inches should be replaced as necessary.
- Occasional pruning and replacement of dead vegetation is necessary. If specific plants are not surviving, more appropriate species should be used. Watering may be required during prolonged dry periods.
- See Green Infrastructure Supplemental document. for a sample O & M Manual.

702.03b Rain Gardens

A rain garden is a shallow, excavated landscape feature or a saucer-shaped depression that temporarily holds runoff for a short period of time. Rain gardens typically consist of an absorbent-planted soil bed; a mulch layer; a gravel filter chamber; and planting materials such as shrubs, grasses, and flowers. An overflow conveyance system is included to pass larger storms. Captured runoff from downspouts, roof drains, pipes, swales, or curb openings temporarily ponds and slowly filters into the soil over 24 to 72 hours.

Applications:

Rain gardens can be primary or secondary practices on residential, commercial, industrial, or institutional sites. This practice is typically used to treat runoff from small impervious areas like rooftops, driveways, and sidewalks. Rain gardens can also be used in retrofitting and redevelopment applications and in series where existing slopes require energy dissipation.

Performance:

When designed according to the guidance below, the contributing impervious area may be subtracted from total impervious cover when calculating WQ_v. Post development CN’s for areas served by rain gardens may be assumed to be “open space in good condition” when computing Qv.

Constraints:

The following constraints are critical when considering the use of rain gardens to capture and treat stormwater runoff:

- **Topography:** Rain gardens require relatively flat slopes (<5%) to accommodate runoff filtering through the system. Some design modifications can address this constraint through the use of infiltration berms, terracing, and timber or block retaining walls on moderate slopes.

- **Soils:** Clayey soils or soils that have been compacted by construction equipment greatly reduce the effectiveness of this practice. Loosening of the compacted soils may improve drainage capability.

- **Drainage Area:** The drainage area to a rain garden should be relatively small. A single rain garden should be designed to receive flow from a drainage area equal to or less than <u>2,000 ft^2</u> to <u>10,000 ft^2</u>

- **Infrastructure:** The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer, storm drains, electricity) will influence rain garden design and construction. Landscape designers should also consider overhead electrical and telecommunication lines when selecting trees to be planted.

- **Location:**

  - Lot by lot use is not recommended in residential subdivisions due to removal by homeowners.
  - Rain garden excavation in areas with heavy tree cover may damage adjacent tree root systems.

Design Guidance:

The following conditions should be considered when designing rain gardens:

- **Conveyance:** Conveyance to and from a rain garden shall ensure non-erosive conditions. Energy dissipation shall be provided for downspout discharges using a plunge area, rocks, splash blocks, stone dams, etc. Runoff shall enter a rain garden at the surface through grass swales and/or a gravel bed. A minimum internal slope of one percent should be maintained and a shallow berm surrounding the rain garden is recommended to avoid short-circuiting. For sloped applications, a series of rain gardens can be used as “scalloped” terraces to convey water non-erosively.

- **Treatment:** Rain gardens shall meet the following conditions:

  - The drainage area to a rain garden serving a single lot in a residential subdivision shall be 2,000 ft^2 or less. The maximum drainage area to a rain garden for all other applications is 10,000 ft^2. Micro-bioretention (REFERENCE) or bioretention (REFERENCE) should be considered when these requirements are exceeded.

- Rain gardens shall capture and store the WQ_v.
- Excavated rain gardens work best where HSG A and B are prevalent. In areas of HSG C and D, at-grade applications should be considered.
- A minimum of six to twelve-inch layer of planting soil shall be placed at the invert.
- A mulch layer two to three inches deep shall be applied to the planting soil to maintain soil moisture and to prevent premature clogging.
- The planting soil and mulch shall conform to the specifications found in Green Infrastructure Supplemental document.

- **Landscaping:** A rain garden should be located in full to partial sun, at least two feet above the seasonal high water table and be 12 to 18 inches deep. Landscaping plans shall clearly specify how vegetation will be established and managed. Plants selected for use in a rain garden should tolerate both saturated and dry conditions and are native or adapted to Indiana. Neatly trimmed shrubs, a crisp lawn edge, stone retaining walls, and other devices can be used to keep a rain garden neat and visually appealing. Landscaping plans shall be provided according to the guidance in Green Infrastructure Supplemental document..

Construction Criteria:

The following items should be addressed during the construction of projects with rain gardens:

- **Erosion and Sediment Control:** Rain gardens should not be constructed until the contributing drainage area is stabilized. During construction, runoff should be diverted away and the use of heavy equipment avoided to minimize compaction.

- **Planting Soil:** Planting soil should be mixed on-site prior to installation. If poor soils are encountered beneath the rain garden, a four-inch layer of washed gravel (1/8 to 3/8 inch gravel preferred) may be used below the planting soil mix.

- **Landscape Installation:** The optimum planting time is during autumn months. Spring planting is also acceptable but may require watering.

Inspection:

- Regular inspections shall be made during the following stages of construction:

  - During excavation to subgrade and placement of planting soil.
  - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria: The following items should be addressed to ensure proper maintenance and long-term performance of rain gardens:

- Rain garden maintenance is generally no different than that required of other landscaped areas.
- Privately owned practices must have a maintenance plan and shall be protected by easement, deed restriction, ordinance, or other legal measures preventing its neglect, adverse alteration, and removal.
- The top few inches of the planting soil should be removed and replaced when water ponds for more than 48 hours. Silts and sediment should be removed from the surface of the bed as needed.
- Where practices are used to treat areas with higher concentrations of heavy metals (e.g., parking lots, roads), mulch should be replaced annually. Otherwise, the top two to three inches should be replaced as necessary.
- Occasional pruning and replacement of dead vegetation is necessary. If specific plants are not surviving, more appropriate species should be used. Watering may be required during prolonged dry periods.
- See Green Infrastructure Supplemental document. for a sample O & M Manual.

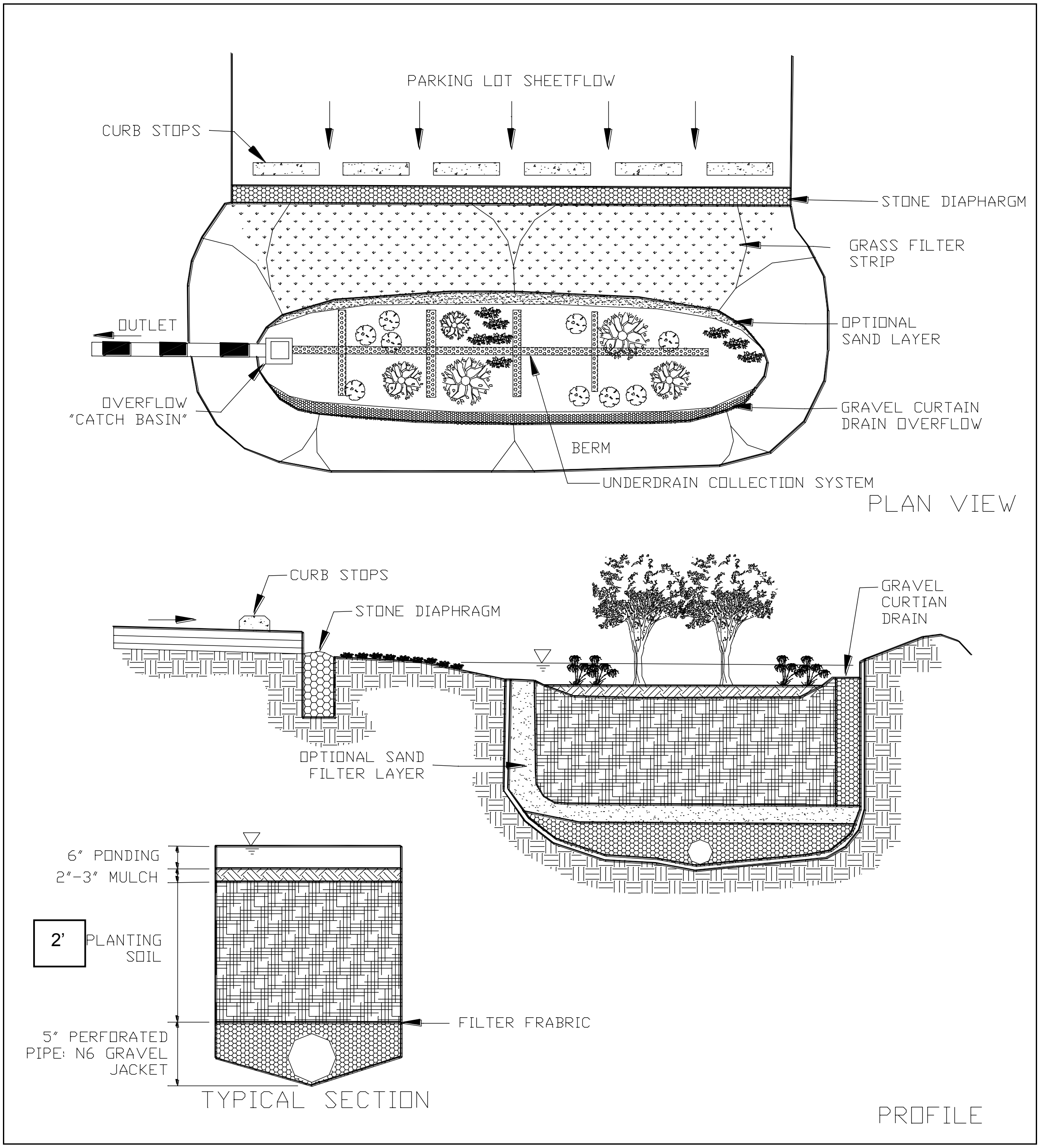

FIGURE 702-12: Bioretention Area

Bioretention Operation, Maintenance,
and Management Inspection Checklist for BMP Owners

Site Name: ____Owner changed since last inspection? Y N

Owner name, address and phone number:____

Location: ____

Date: ____

Time: ____

Inspector Name: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Debris Cleanout (Inspect monthly)		
1. Bioretention area and contributing areas clean of debris		
2. Litter (branches, etc.) has been removed		
Vegetation (Inspect monthly)		
1. Plant height note less than design ponding depth		
2. Plant composition according to approved plan		
3. Grass height not more than 6 inches		
4. No evidence of erosion		

Additional Comments and Actions to be Taken **Timeframe:**

FIGURE 702-13: Private Operation, Maintenance & Management – Bioretention Areas

702.04 Sand Filters

Sand filters are structural stormwater controls that temporarily store stormwater and pass it through a filter bed of sand. Most sand filter systems contain two chambers. The first chamber is a sedimentation chamber that removes floatables and heavy sediments. The second chamber is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can be partially or fully exfiltrated into the surrounding soil in areas with porous soils.

Sand filters are primarily designed as off-line structures for stormwater quality and typically need to be used in conjunction with another structural BMP to provide water quantity control.

Refer to figures 702-16 through 702-18 for schematics of sand filters.

Site and Design Considerations

1. The maximum effective drainage area to an individual stormwater filtering system is less than 10 acres. Sand filters cannot be designed to treat the entire contributing drainage area.

2. The design volume must be based on the WQv and must be designed to fully empty in 36 hours.

3. Adequate pretreatment (e.g., filter strips, see Section 702.06) is required to prevent sediment from overloading the filters. The inlet structure to the filtration chamber must be designed to spread the flow uniformly across the surface of the filter media. Stone riprap or other dissipation devices must be installed to prevent gouging of the sand media and to promote uniform flow.

4. The allowable minimum head is one foot. The maximum allowable head is 6 feet.

5. Construct sand bed to a depth of at least 18 inches.

6. Underdrain pipes must consist of main collector pipes and perforated lateral branch pipes. Reinforce the underdrain piping to withstand the weight of the overburden. Internal diameters of lateral branch pipes must be 4 inches or greater (6 inches preferred) and perforations should be 1/8 inch. Space perforations a maximum of 6 inches between rows. All piping must be schedule 40 polyvinyl chloride or greater strength or similarly rated HDPE pipe. The minimum grade of piping should be 1/8 inch per foot (1% slope). Provide access for cleaning all underdrain piping.

7. Surface filters may have a grass cover to aid in pollution adsorption.

8. Establish vegetation over the contributing drainage areas before runoff can be accepted into the facility.

9. Two allowable surface sand bed filter configurations are:

   Sand Bed with Gravel Layer

a) Top layer of sand must be a minimum of 18 inches of 0.02 - 0.04 inch diameter sand (smaller sand size is acceptable).
b) A layer of one-half to 2-inch diameter gravel under the sand must be provided for a minimum of 2 inches of cover over the top of the under-drain lateral pipes.
c) No gravel is required under the lateral pipes.
d) A layer of geotextile fabric (permeable filter fabric) must separate the sand and gravel.

Sand Bed with Trench Design

a) Top layer of sand is to be 12-18 inches of 0.02 - 0.04 inch diameter sand (smaller size is acceptable).
b) Laterals to be placed in trenches with a covering of one-half to 2-inch gravel and geotextile fabric.
c) The lateral pipes are to be underlain by a layer of drainage matting.
d) A presettling basin and/or biofiltration swale is recommended to pretreat runoff discharging to the sand filter.
e) A maximum spacing of 10 feet between lateral underdrain pipes is recommended.

Performance Standards

Sand filters designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Pollutant	Percent Reduction
TSS	85%
Bacteria	40-80%
BOD	60%
Total P	65%
Total N	50%
Metals	60%

Advantages

1. Applicable to small drainage areas
2. Good for highly impervious areas
3. Good retrofit capability

Disadvantages

1. High maintenance
2. Not recommended for areas with high sediment content in stormwater.
3. Relatively costly
4. Possible odor problems

Allowable Sand Filter Variations

There are two primary sand filter system designs, the surface sand filter and the perimeter sand filter.

1. **Surface Sand Filter**- The surface sand filter is a ground-level open-air structure that consists of a pretreatment sediment forebay and a filter bed chamber. This system can treat drainage areas up to 10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with an earthen embankment or as a concrete structure. Refer to Figure 702-16 for a schematic of a surface sand filter.
2. **Perimeter Sand Filter**- The perimeter sand filter is an enclosed filter

system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control. Refer to Figure 702-17 for a schematic of a perimeter sand filter.

3. **Underground Sand Filter**- The underground sand filter is intended primarily for extremely space-limited and high-density areas. Refer to Figure 702-18 for a schematic of an underground sand filter.

Maintenance

Each BMP must have an operations and maintenance plan submitted to the City for approval and maintained and updated by the BMP owner. Refer to Figure 702-19 for a checklist for BMP owner routine operation, maintenance and inspection of sand filters. The City will perform annual BMP inspections, using a similar checklist. The owner shall be responsible for maintenance costs and the annual inspection fee. See Section 103.04 for a schedule of fees.

1. A stormwater management easement and maintenance agreement is required for each facility. The maintenance covenant must require the owner of the sand filter to annually clean the structure. A copy of the easement should be included in the digital copy of the BMP operations and maintenance manual.

2. Scrape off sediment layer buildup during dry periods with steel rakes or other devices.

3. Replace some or all of the sand when permeability of the filter media is reduced to unacceptable levels, which shall be specified in the design of the facility. A minimum infiltration rate of 0.5 inches per hour shall be used for all infiltration designs.

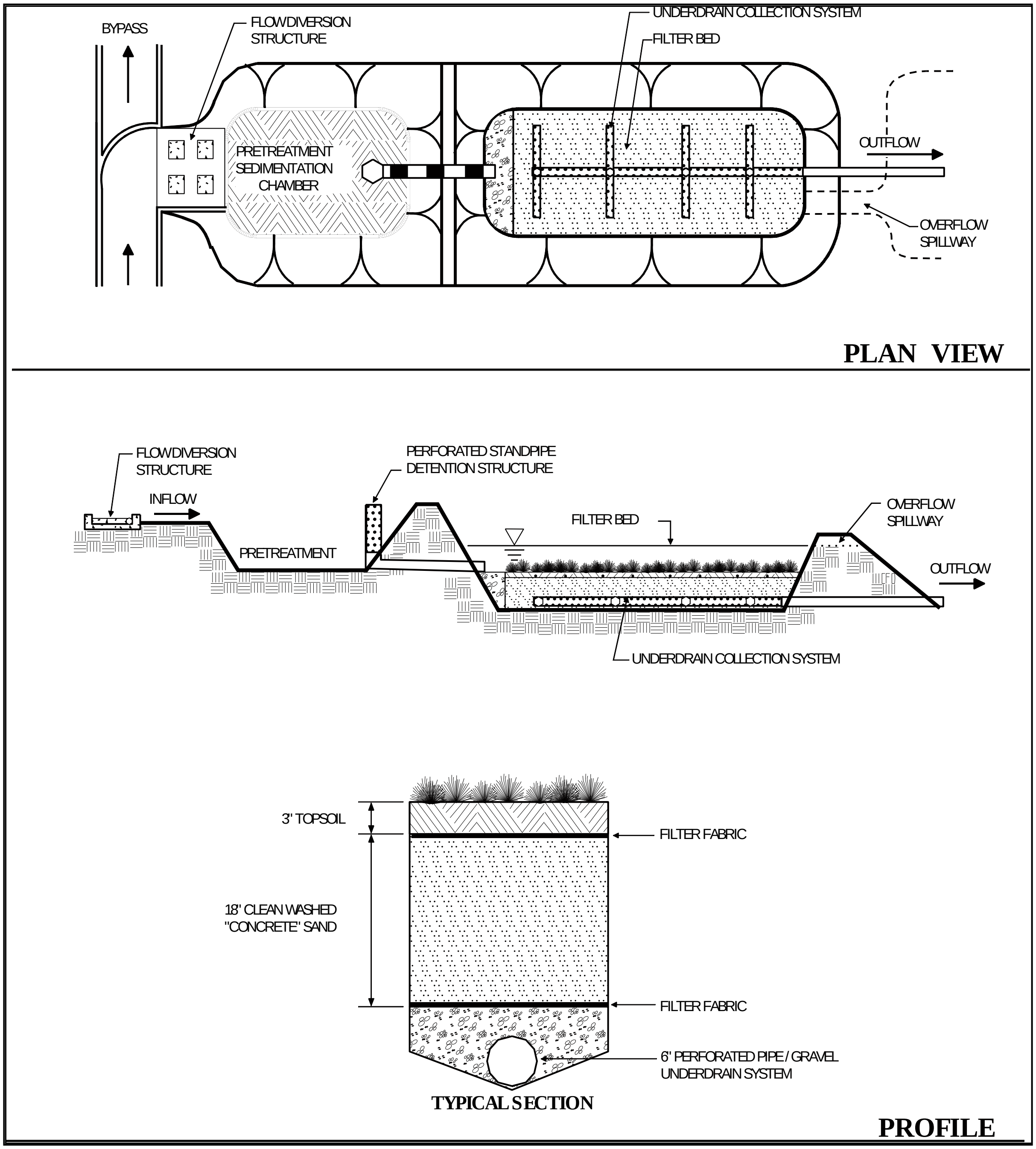

FIGURE 702-14: Surface Sand Filter

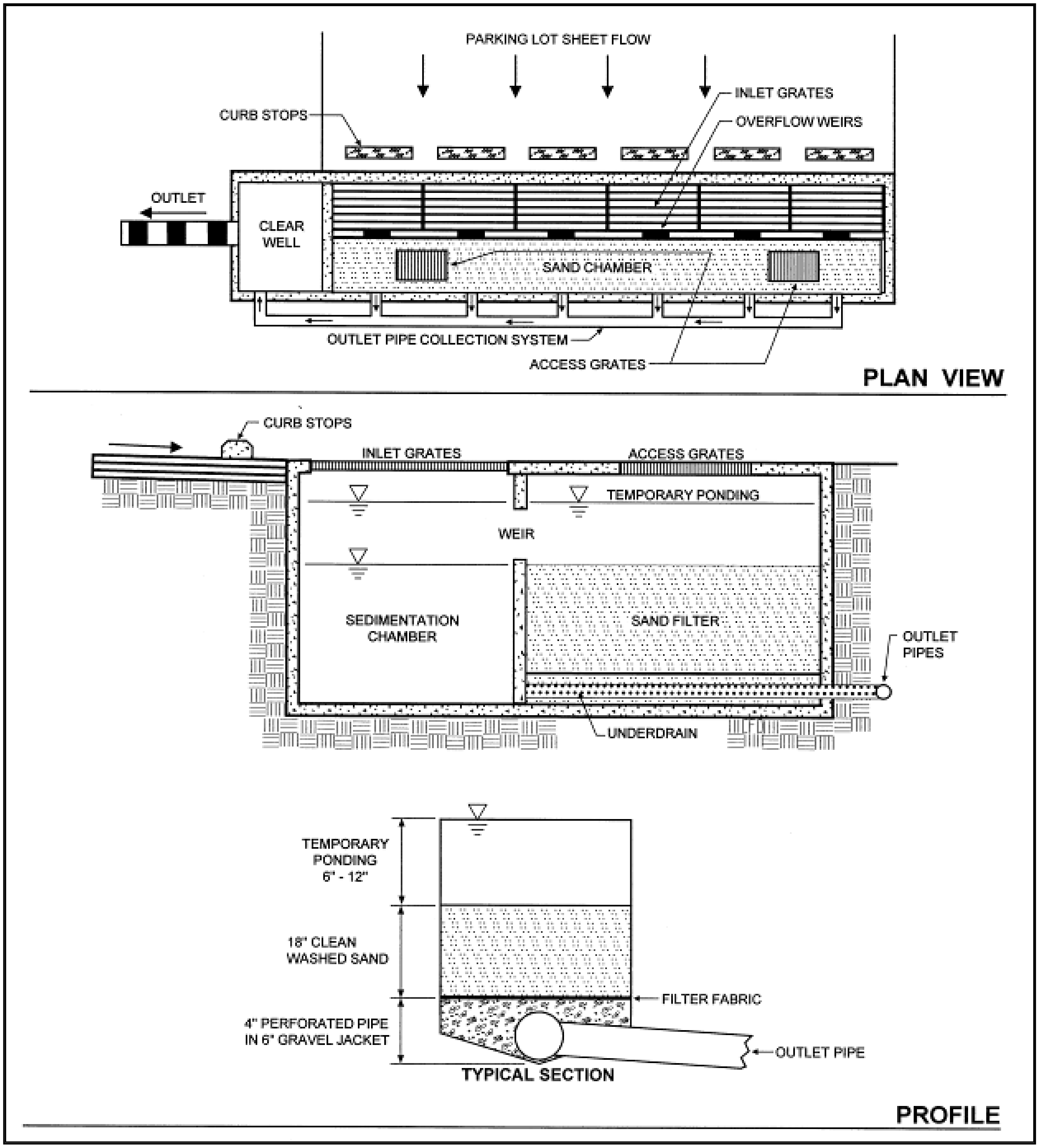

FIGURE 702-15: Perimeter Sand Filter

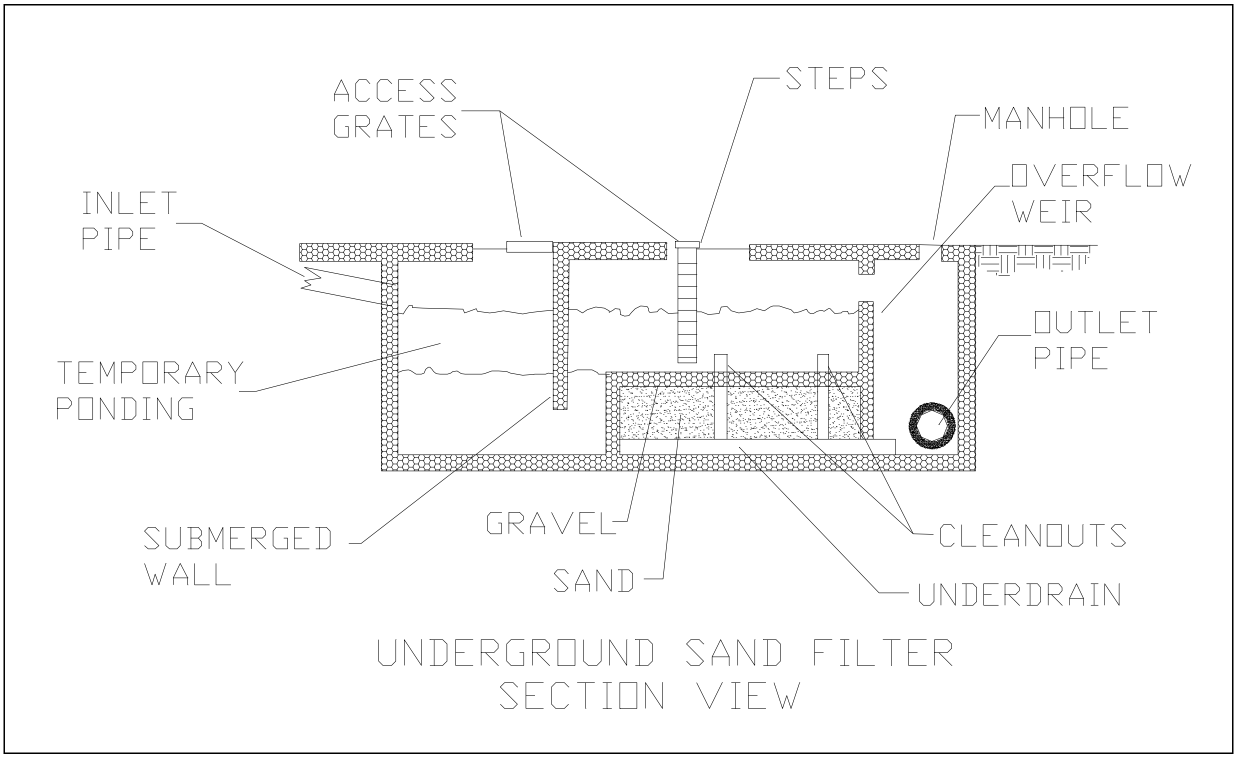

FIGURE 702-16: Underground Sand Filter

Sand Filter Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Site Name: ___________________________ Owner changed since last inspection? Y N

Owner name, address and phone number:___________________________

Location: ___________________________

Date: ___________________________

Time: ___________________________

Inspector Name: ___________________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Debris Cleanout (Inspect monthly)		
1. Filtration facility		
2. Inlet and outlet		
Oil and Grease (Inspect monthly)		
1. Evidence of filter surface clogging		
Vegetation (Inspect monthly)		
1. Surrounding areas stabilized		
2. Evidence of erosion		
Water retention where required (Inspect monthly)		
1. Water holding chambers at normal pool		
2. No evidence of leaking		
Sediment Deposition (Inspect annually)		
1. Filter chamber free of sediments		
2. Sedimentation chamber not more than 50% full		

FIGURE 702-17: Private Operation, Maintenance & Management – Sand Filter

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Structural Components (Inspect annually)		
1. Structural soundness (deterioration evident)		
2. Grates in good condition		
3. No evidence of structural spalling or cracking		
Outlet/Overflow Spillway (Inspect annually)		
1. Good condition, no need for repairs		
2. No evidence of erosion		
Other (Inspect annually)		
1. No odors		
2. Evidence of flow bypassing the filter		

Additional Comments

Actions to be taken: **Timeframe:**

702.05 Water Quality Swales

Dry water quality swales are channels designed and constructed to capture and treat stormwater runoff within dry cells formed by check dams or other means. Dry water quality swales are also described as biofiltration swales. These swales are designed with a limited slope for slow, shallow flow to allow particulates to settle out and to promote infiltration. Water quality swales are limited to areas with low impervious acreage, such as residential and industrial developments.

Dry swales are channels designed with a filter bed and underdrain system. They are designed to filter and infiltrate the entire WQ_v through the bottom of the swale. Runoff is collected by a perforated pipe and discharged at the outlet. Water quality swales are dry most of the time and are therefore well suited for residential areas. Refer to Figure 702-20 for a schematic of a dry swale.

Site and Design Considerations

The following site and design criteria must be followed:

1. Water quality swales treat only the WQv. An additional measure is needed to provide detention in conjunction with the water quality swale. The swales can be designed as on-line or off-line structures. Larger storms pass non-erosively through the channels.

2. Water quality swales are limited to peak discharges generally less than 5 to 10 cfs and runoff velocities less than 2.5 ft/sec. The maximum drainage area is 5 acres. The maximum ponding time must be less than 48 hours, and a minimum ponding time of 30 minutes is recommended.

3. The maximum design flow depth is 1 foot, for all storm events, with a ponding depth of 18 inches at the end of the channel.

4. Swale cross-section must have side slopes of 3:1 (h:v) or flatter. Bottom widths must be between 2-8 feet wide.

5. Underlying soils shall have a high permeability (fc > 0.5 inches per hour). Seasonally high water table must be greater than 3 feet below the bottom of the swale. The seasonal high water table must be determined by a practicing soil scientist of geo-technical investigation.

6. Water quality swales must have a minimum length of 100 feet.

7. Provide a sediment forebay at the inlet to the swales.

8. The underdrain must have a minimum of 2 feet of planting soil above the crown.

9. Locate the swale and all of its components within a drainage easement. The easement should include access to the BMP.

Performance Standards

Water quality swales designed, constructed and maintained (on a 4% or flatter slope) as noted in this manual provide the following pollutant reductions:

Pollutant	Percent Reduction
TSS	80%
Bacteria	- 55%
BOD	10%
Total P	83%
Total N	92%
Metals	75%

Advantages

1. Typically well accepted in residential settings
2. Inexpensive.
3. Combines water quality treatment with runoff conveyance.
4. Reduces runoff velocities.
5. Low maintenance.

Disadvantages

1. Cannot be used on steep slopes.
2. Can provide a limited amount of stormwater quantity control.
3. Shown to export bacteria to stormwater

Maintenance
Each BMP must have an operations and maintenance plan submitted to the City for approval and maintained and updated by the BMP owner. Refer to Figure 702-21 for a checklist for BMP owner routine operation, inspection and maintenance of water quality swales. The City will perform annual inspections. The BMP owner shall be responsible for maintenance costs and the annual inspection fee.

1. A stormwater management easement and maintenance agreement is required for each facility. The maintenance covenant must require the owner of the grassed swale to periodically clean the structure. A copy of the easement should be included in the digital copy of the BMP operations and maintenance manual.

2. Provide adequate access for inspection and maintenance.

3. Dry swales shall be maintained to keep grass cover dense and vigorous.

4. At a minimum, maintenance shall include periodic mowing, occasional spot reseeding, and weed control. Swale grasses must never be mowed close to the ground. Grass heights in the 4 to 6 inch range are recommended.

5. Fertilization of grass swale shall be done when needed to maintain the health of the grass, with care not to over-apply the fertilizer.

6. Remove sediment accumulated in forebay when it is 50% full.

7. The planting soil should be removed or replanted when ponding time exceeds 36 hours.

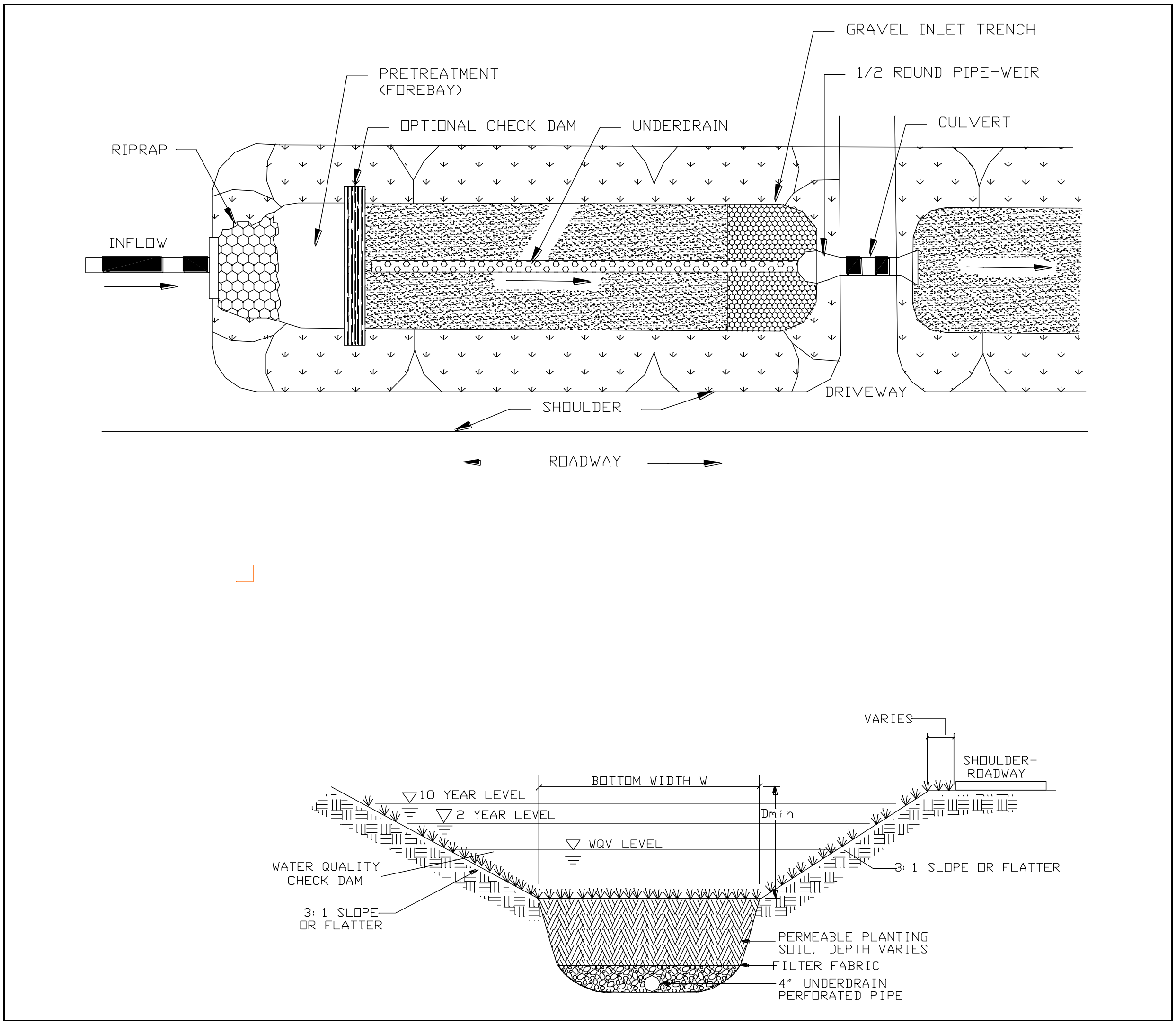

FIGURE 702-18: Dry Swale

**Water Quality Swale Operation, Maintenance,
and Management Inspection Checklist for BMP Owners**

Site Name: ______________________ Owner changed since last inspection? Y N

Owner name, address and phone number:______________________

Location: ______________________

Date: ______________________

Time: ______________________

Inspector Name: ______________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Debris Cleanout (Inspect monthly)		
1. Contributing drainage areas free from debris		
Vegetation (Inspect monthly)		
1. Mowing done when needed		
2. No evidence of erosion		
3. Ponding areas dry after 36 hours		
Check Dams or Energy Dissipators *(Inspect annually)*		
1. No evidence of flow going around structure		
2. No evidence of erosion at the downstream toe		
3. Soil permeability		
Sediment Forebay		
1. Sediment cleanout needed (clean out when 50% full)		

FIGURE 702-19: Private Operation, Maintenance & Management – Water Quality Swale

Additional Comments and Actions to be Taken **Timeframe**:

702.06 Biofilters

Biofilters are densely vegetated sections of land, designed to treat runoff from and remove pollutants through vegetative filtering and infiltration. Biofilters must receive runoff from adjacent areas as sheet flow. The vegetation slows the runoff and filters out sediment and other pollutants. However, the TSS removal provided is less than 80 percent. Therefore, biofilters must be used in a treatment train in conjunction with other management practices to provide the 80 percent performance goal.

Biofilters are best suited to treating runoff from roadways, rooftops, small parking areas and pervious areas. They can be easily incorporated into residential development as land-use buffers and setbacks.

Figure 702-22 is a schematic of a filter strip. Figure 702-23 is a schematic of a riparian buffer, and Figure 702-24 is a schematic of a level spreader or flow spreader.

Allowable Biofilter Variations

Filter strip: A filter strip is a uniformly graded and densely vegetated strip of land. The vegetation can be grasses or a combination of grass and woody plants. Pollutant removal efficiencies are based upon a 50-foot wide strip. Refer to Figure 702-22 for a schematic of a filter strip. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion.

Riparian buffer: A riparian buffer is a strip of land with natural, woody vegetation along a stream or other watercourse. Besides the undergrowth of grasses and herbaceous vegetation, the riparian buffer includes deep rooted trees. The 20-foot zone closest to the stream or watercourse (Zone 1) contains the trees, while the outer 30 feet of the riparian buffer contains a dense stand of grasses. The overall width of the riparian buffer is 50 feet. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion. Refer to Figure 702-23 for a schematic of a riparian buffer.

Site and Drainage Considerations

The following site and drainage considerations must be included in the BMP plan:

1. To ensure sheet flow into the filter strips and riparian buffers, flow spreaders or level spreaders must be designed and installed where concentrated runoff flows into filter strips or riparian buffers.

2. Level Spreader: The grade of a level spreader shall be 0%. The channel grade for the last 20 feet of the dike or diversion entering the level spreader must be less than or equal to 1% and designed to provide a smooth transition into spreader. The depth of a level spreader as measured from the lip must be at least 6 inches. The level spreader lip must be constructed on undisturbed soil (not fill material) to uniform height and zero grade over length of the spreader. The maximum drainage area to the level spreader shall be 10 acres or less with the optimal size being less than 5 acres. The maximum flow into the level spreader must be 30 cfs or less.

3. Appropriate length, width, and depth of level spreaders shall be selected from the following table.

Design Flow (cfs)	Entrance Width (ft)	Depth (ft)	End Width (ft)	Length (ft)
0-10	10	0.5	3	10
10-20	16	0.6	3	20
20-30	24	0.7	3	30

4. Capacity of the spreader, filter strip and riparian buffer length (perpendicular to flow) must be determined by estimating the volume of flow that is diverted to the spreader for water quality control.

5. The released runoff to the outlet must be on undisturbed stabilized areas in sheet flow and not allowed to re-concentrate below the structure.

6. Slope of the filter strip from a level spreader must not exceed 10 percent.

7. All disturbed areas must be vegetated immediately after construction.

8. The minimum filter strip width is 50 feet.

9. Filter strips must be designed for slopes between 2 percent and 6 percent.

10. Ensure that flows in excess of design flow move across and around the filter strip without damaging it.

11. Filter strips can be used effectively as pretreatment measures. The minimum sizing criteria are as follows:

Source: Claytor and Schueler, 1996

Parameters	Impervious Area				Pervious Area (lawns, etc.)			
Maximum inflow approach length (ft)	35		75		75		100	
Filter strip slope (max = 6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter strip minimum length (ft)	10	15	20	25	10	12	15	18

12. Riparian buffers: The use of buffers is limited to drainage areas of 10 acres or less with the optimal size being less than 5 acres.

13. Slope of the buffer from a level spreader cannot exceed 10 percent.

14. Top edge of buffer must directly abut the contributing impervious area and follow the same elevation contour line.

15. Biofilters and level spreaders must be located within a drainage easement. A copy of the easement should be included in the digital copy of the BMP operations and maintenance manual.

Performance Standards

Biofilters designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Pollutant	**Percent Reduction** **(**riparian buffer/filter strip)
TSS	60/30%
Bacteria	40%/40%
BOD	40/10%
Total P	35/10%
Total N	25/10%
Metals	70/30%

Advantages

1. Filter strips and riparian buffers can easily be incorporated into new development design.
2. Low maintenance once a dense ground cover is established in filter strips and level spreaders and once trees and other woody vegetation is established in riparian buffers.
3. Riparian buffers provide wildlife habitat.

Disadvantages

1. Filter strips, riparian buffers and level spreaders have limited drainage areas.
2. Constructing a level lip on a level spreader can be difficult. Failure to construct a level lip makes the level spreader ineffective.

Maintenance

A BMP operations and maintenance plan is required for each BMP. The plan must be submitted to the City for approval and maintained and updated by the BMP owner. Refer to figure 702-25 for a BMP owner's routine checklist for inspection and maintenance of filter strips and riparian buffers. The City shall perform annual inspections, using a similar checklist. The BMP owner is responsible for maintenance costs and the annual inspection fee.

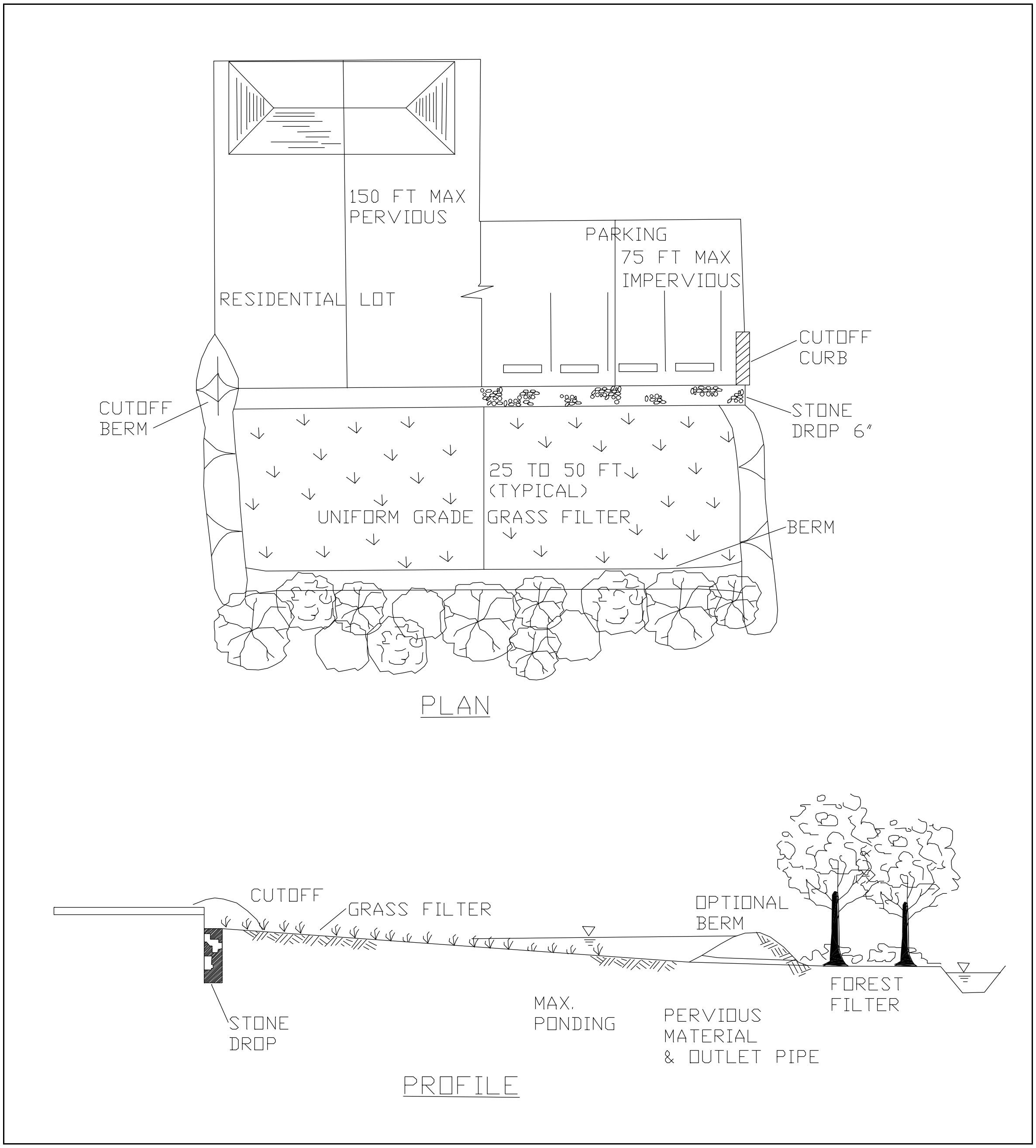

FIGURE 702-20: Filter Strip

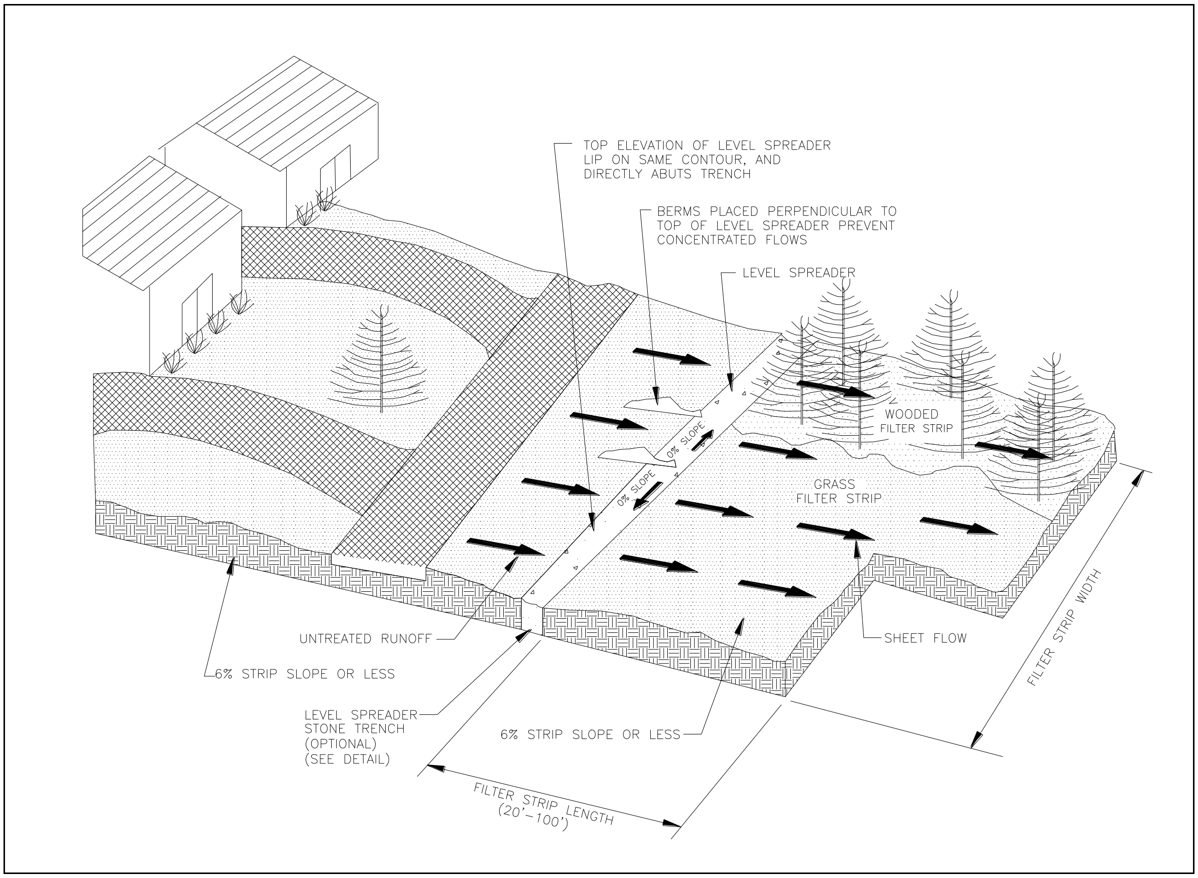

FIGURE 702-21: Buffer
(Source: Controlling Urban Runoff)

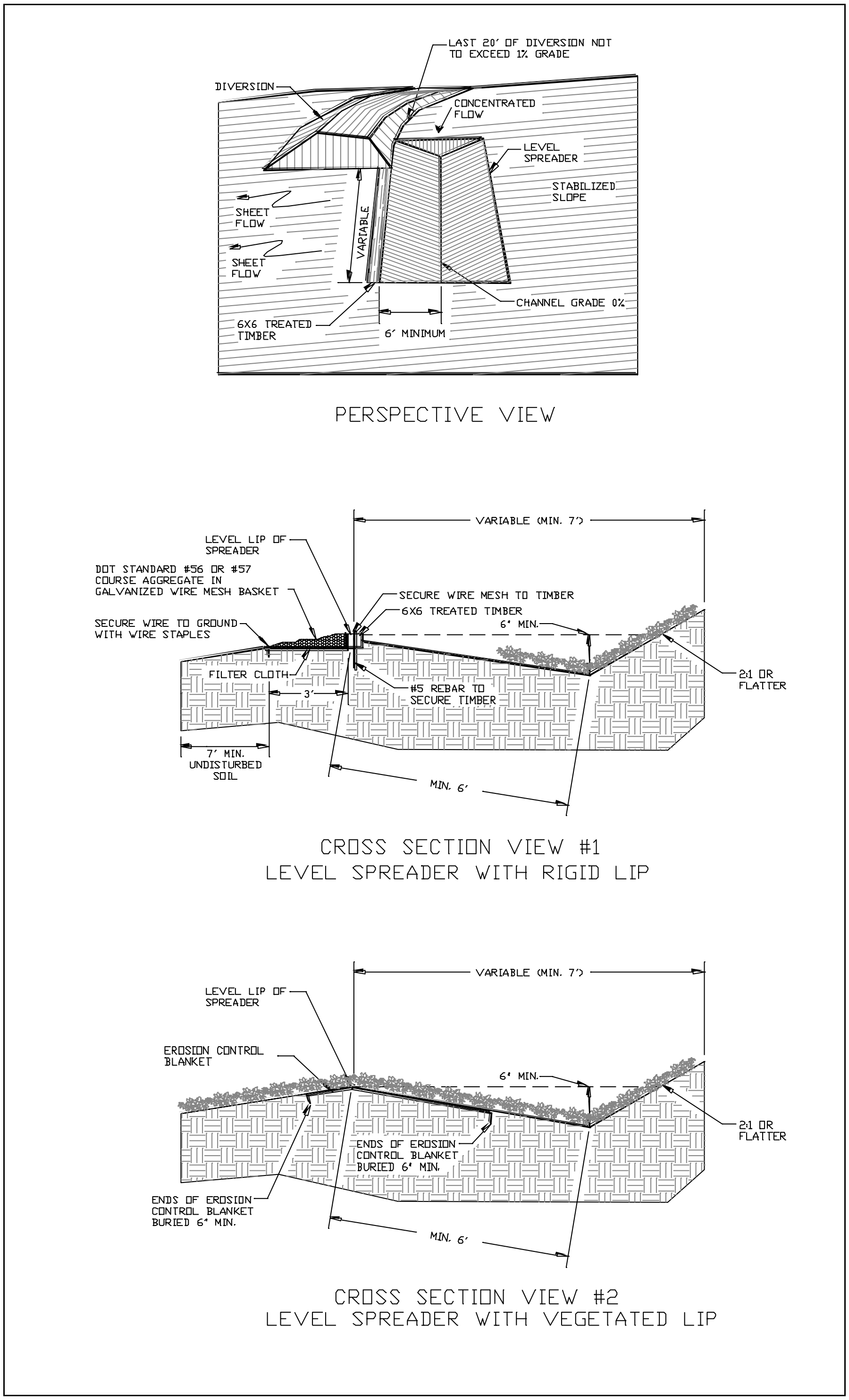

FIGURE 702-22: Level Spreader
(Source: North Carolina Erosion And Sediment Control Planning And Design Manual, 1988)

Biofilter and Buffer Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Site Name: ___________________________________ Owner changed since last inspection? Y N

Owner name, address and phone number:____

Location: ____

Date: ____

Time: ____

Inspector Name: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Vegetation (Inspect monthly)		
1. Plant composition according to approved plan		
2. Vegetation is healthy		
3. Grass height not more than 6 inches		
4. No evidence of erosion or channelization or rilling of runoff in the vegetative areas		
Level spreader (Inspect monthly)		
1. Vegetation is healthy		
2. Lip of spreader showing no signs of erosion		
3. Sediment noted in spreader?		
Debris Cleanout (Inspect monthly)		
1. Litter / floatable accumulation?		

Additional Comments and Actions to be Taken: **Timeframe**:

FIGURE 702-23: Private Operation, Maintenance & Management – Biofilters and Buffers

702.07 Catch Basin Inserts

Many variations of catch basin insert designs exist. Catch basin inserts can be designed and installed in a storm drain system provided the following minimum criteria for the inserts are met:

1. Provide an overflow weir to pass storm events larger than the design storm.

2. Catch basin inserts must meet the 80% TSS removal rate. Verification of the TSS removal rate must be provided by independent testing, not manufacturer testing.

3. If variations of the insert or filter media are available that remove bacteria, hydrocarbons, dissolved metals, or other pollutants verification of those removal characteristics must be provided.

4. If multiple filter media are required to meet site-specific pollutant removal requirements the impact of multiple filter medias on discharge characteristics must be provided showing that the design storms still pass through the insert to the City's standards.

5. Each design for catch basins can have specific maintenance needs or issues. Maintenance requirements must be clearly defined, and a specific maintenance agreement submitted to the City for review and approval.

Supporting documentation from the manufacturer to verify maintenance requirements and pollutant removal rates must be submitted to the City for verification and approval. A maintenance plan must be submitted to the City prior to stormwater management plan approval and maintained and updated by the BMP owner. The BMP owner is responsible for routine maintenance, operation and inspection. The City shall perform annual inspections. The BMP owner is responsible for maintenance costs and the annual inspection fee.

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